DISTRICT OF WEST VANCOUVER
INTEGRATED STORMWATER MANAGEMENT PLAN FOR PIPE, WESTMOUNT, CAVE, TURNER AND GODMAN CREEKS

APPENDIX C

GOLDER HYDRO-GEOTECHNICAL STREAM ASSESSMENT REPORT

January 26, 2009

HYDRO-GEOTECHNICAL STREAM ASSESSMENT

Input to Integrated Stormwater Management Plan for Pipe Creek, Westmount Creek, Cave Creek, Turner Creek and Godman Creek District of West Vancouver, BC

Submitted to:
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REPORT

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Dayton & Knight Ltd. (D&K) to provide geotechnical and hydrogeological support during D&K's on-going development of an Integrated Stormwater Management Plan (ISMP) for the District of West Vancouver, B.C. All work undertaken by Golder was completed in general agreement with the Work Plan outlined in Golder's proposal to D&K dated April 7, 2008. Specifically, Golder carried out a detailed geotechnical assessment of five watercourses (*i.e.*, Pipe, Westmount, Cave, Turner and Godman Creeks) that are located partly within British Pacific Properties (BPP) lands situated north of Highway No. 1 in the District of West Vancouver (Figure 1). The primary objectives of the assessment were identified in Golder's proposal, as follows:

- Complete a desk-top review of existing geotechnical and hydrogeological information/reports, including available historical aerial photographs;
- Complete field reconnaissance surveys as required to identify sections of all stream channels that are potentially susceptible to erosion, based on 1-year return and 100-year return conditions;
- Complete field reconnaissance surveys as required to identify naturals hazards and the corresponding potential effects on the drainage systems, with specific consideration for potential geotechnical hazards related to stormwater management approaches/methods;
- Prepare comments and recommendations on the overall viability of ISMP measures/approaches identified in Metro Vancouver's 2005 "Template for Integrated Stormwater Management Planning", based on an assessment of the interpreted effectiveness of those measures/approaches to manage and/or mitigate potential effects of identified and/or inferred natural hazards;
- Prepare comments on the overall feasibility of infiltrating stormwater runoff in proposed development areas within the overall study area.

The geotechnical comments and recommendations presented in this report were prepared specifically for the geotechnical aspects of the project and relate only to the potential effects on stream channels, banks and sidewall slopes. Investigation, analyses or assessment of issues related to site development and foundation design, the potential for soil and groundwater contamination, as well as biological or archaeological considerations, are outside of the scope of this assessment.

This report shall be read in conjunction with "*Important Information and Limitations of This Report*", which is appended following the text of this report. The reader's attention is specifically drawn to this information as it is essential that it is followed for the proper use and interpretation of this report.

2.0 STUDY AREA

The proposed development area, a portion of which is conceptual at this time, extends northward and upslope from the Upper Levels Highway (Highway No. 1) as shown in Figure 2. The overall project area encompasses portions of a number of generally south-flowing, north-south aligned watercourses including Godman Creek, Turner Creek, Cave Creek, Westmount Creek and Pipe Creek.

The lower portion of the Cypress Bowl Road currently provides access to most of the proposed residential development area. Historical logging on the upper portions of the south-facing slopes utilized a number of now overgrown and partially deactivated logging roads and trails. Two transmission lines and associated right-ofways cross the western portion of the project area. Several mountain biking and/or hiking trails were also noted within the project area.

We understand that the development within BPP lands will include residential subdivision and construction, with related roads and services; however, the specific layout and configuration for the proposed development had not been established at the time of this assessment. All watercourses considered in this assessment were physically examined from their headwater areas to the ocean outfall at Burrard Inlet (Figure 2).

3.0 WORK COMPLETED

All work undertaken by Golder was completed in general conformance with the range of tasks identified in Clause 5 "Hydrogeology/Geotechnical Assessment" and Clause 20 "Natural Hazard Assessment" of Metro Vancouver's Template for Integrated Stormwater Management Planning (Johnson et al., 2005).

3.1 Information Review

Prior to commencing the field reconnaissance surveys, available information related to the overall project area was collected and reviewed, including historical aerial photographs and previous engineering reports. A summary of the historical aerial photographs compiled and reviewed for this assessment are listed in Table 1.

Table 1: Available Historical Aerial Photographs Reviewed

Year	Scale	Reference Number
1926	1:8,600	BA23: Nos. 19-24
1946	1:20,000	A10399: Nos. 146-147 A10497: Nos. 9-11
1954	1:10,000	BC1674: Nos. 75-76, 79-80
1963	1:12,000	BC5060: Nos. 3-5, 127-129
1974	1:10,000	BC5591: Nos. 274-277 BC5592: Nos. 54-57
1979	1:10,000	30BC79044: Nos. 22-26 30BC79052: Nos. 56-59
1984	1 :24,000	A26511: Nos. 51-52, 69-70
1991	1 :24,000	FF9131: Nos. 204-206
1997	1 :30,000	FFC VCR 9700: Nos. 253-254
2004	1 :20,000	SRS6929: No. 428

The following observations and interpretations have been developed from review of the historical aerial photographs.

<u>1926</u>

Marine Drive exists with some residential development locally both upslope and downslope. There is no visible evidence of landslides or stream channel instability within or adjacent to the project area. A transmission line is present across Godman and Turner Creeks.

<u>1946</u>

More residential development has occurred south of Marine Drive. A steep switchback (logging?) road ascends the east side of Rodgers Creek. No visible evidence of landslides or stream channel instability within or adjacent to the project area.

<u>1954</u>

Recent logging of the slopes within the project area has occurred. Some small landslides (debris avalanches), likely related to yarding activities, have occurred on the steeper slope areas adjacent to Pipe and Westmount Creeks.

<u>1963</u>

No further visible indications of landslides or stream channel instability. Logged areas have started to green up. The Upper Levels Highway has been constructed.

<u>1974</u>

The switchback road (pre-cursor to the Cypress Bowl Road) to Cypress Mountain exists. No visible evidence of landslides associated with this road.

<u>1979</u>

No visible changes other than increased development south of the Upper Levels Highway.

<u>1984</u>

No visible evidence of landslides or stream channel instability within or adjacent to the project area.

<u>1991</u>

No visible evidence of landslides or stream channel instability within or adjacent to the project area.

<u>1997</u>

No visible evidence of landslides or stream channel instability within or adjacent to the project area.

<u>2004</u>

No visible evidence of landslides or stream channel instability within or adjacent to the project area.

The relevant geotechnical reports reviewed included Golder's 2007 document, "Geotechnical Creek Setback Assessment, Proposed Upper Rodgers Creek Residential Development, West Vancouver, B.C." prepared for InterCAD Services Ltd.

3.2 Field Assessment

Field reconnaissance surveys and concurrent geotechnical field assessments were carried out by Mr. Russ Wong, P.Geo. accompanied by Mr. Brad Panton, E.I.T. and Mr. Andrew Nelson, field technician, of Golder on August 28, 29 and September 4, 9, 10 and 11, 2008. During the assessment all stream channels and adjacent slopes, soil and bedrock conditions, and the site/slope drainage were examined with respect to the presence or absence of existing natural stream-related hazards, and to stream-related hazards that might be initiated or exacerbated by increased streamflows due to stormwater input. All stream channels were traversed downstream from their headwaters to determine if hazards, such as debris flows and debris floods, could initiate upslope of the BPP development area and potentially affect the proposed downslope development. Basic measurements were made using clinometer, graduated tape and compass methods. Local soil characteristics were determined by inspection of exposures along road and right-of-way cuts and streambanks. Traverse notes and field measurements are compiled in Appendix I. Weather during the field reconnaissance period ranged from cool and wet to sunny and warm with generally good visibility at ground level. A number of site photographs were taken and are on file in Golder's Abbotsford office.

Following completion of the field reconnaissance, pertinent geotechnical information that would aid in establishment of safe development setbacks from the streams was summarized. The results of the field reconnaissance are reported herein.

4.0 PHYSICAL ATTRIBUTES OF THE SITE AND SURROUNDING TERRAIN

4.1 Subsurface Conditions

Review of published surficial and bedrock geology maps, together with field observations, indicate that the project area is generally underlain by a thin mantle of rubbly colluvial materials with alluvial deposits locally along stream channels. The colluvial materials are underlain by dense till and/or granitic bedrock of the Mesozoic-aged Coast Plutonic complex. Sections of all the surveyed streams were underlain by granitic bedrock ranging from quartz diorites to granodiorites. Similar bedrock was also exposed along the cutslopes of both Cypress Bowl Road and the Upper Levels Highway in the project area. Locally, up to 2 m or more of grey, till containing sub-rounded granitic cobbles and boulders was exposed along stream banks. Based on these observed exposures and landforms, the thickness of the till appears to generally increase both southward (*i.e.* downslope) and eastward (*i.e.* across the slope) from the project area.

4.2 Groundwater

The project area is generally covered by a thin mantle of relatively permeable colluvial soils, which are underlain at shallow depths by till and granitic bedrock of comparatively low permeability. Based on our direct field observations, shallow "perched" water table conditions likely occur within both the colluvial and alluvial deposits, due to the restricted vertical (*i.e.* downward) movement of groundwater through the underlying till and/or bedrock. It is possible that lenses or discontinuous layers of relatively permeable, granular sediments may be locally present within the till. Seepage (*i.e.* groundwater discharge) and potential seepage erosion may occur in areas where seepage daylights onto sloping terrain; however, evidence of such erosion (either active or historical) was not observed during the reconnaissance survey.

Small areas of poorly-drained terrain were observed in localized areas of hummocky topography and on some gently sloping surfaces (*e.g.* the tops of bedrock benches), or where previous surface grading and logging works were carried out.

4.3 Local Topography and Geomorphology

The project area is situated on mainly south-facing, moderate to moderately steep (35 % to 60 %) slopes with erosion-resistant granitic bedrock at relatively shallow depths (*i.e.* generally less than 1 to 2 m). Bedrock comprises the streambed and/or immediate streambanks along most of the stream reaches assessed. Locally, the slope morphology is strongly bedrock-controlled with benches and scarps forming moderately steep to steep

(60 % to greater than 70 %) slopes over short slope lengths of generally less than 20 m. For the most part, the streams are not incised deeply into the bedrock (*i.e.* generally less than about 3 m vertical) and, therefore, ravines with long and steep sidewall slopes are not well-developed except locally where the till appears to be thicker.

Upstream of the Upper Levels Highway, the streams within the assessed reaches were most commonly contained within poorly to moderately defined channels that generally ranged from 0.5 m in width near their headwaters to 2.5 m in width near the Upper Levels Highway. As noted above, bedrock streambeds and banks are common. Where a streambed is underlain by a planar bedrock joint surface, the stream commonly has multiple channels over a 10 m to 25 m width often separated by thin remnants of till and/or colluvial materials.

The proposed development area is largely undeveloped with greater than 75 % of the area covered with a moderately dense mix of second growth forest composed of younger deciduous (mainly maple and alder) and older coniferous trees (mainly Douglas Fir and Western Red Cedar), the latter with trunk diameters of up to approximately 0.75 m. Variable undergrowth, consisting primarily of ferns, Salmonberry, Huckleberry and Blackberry, was present on and adjacent to the streams and proximal to the Cypress Bowl Road and Upper Levels Highway.

Downstream from the Upper Levels Highway, natural slopes are gentle to moderate (range from about 20 % to 35 %) and the streams have largely been incorporated into the residential landscape, except those reaches that pass through parks or rare undeveloped areas. Within many of the residential lots, the streams are partially to wholly contained within constructed channels of varying structural integrity and dimensions.

At the time of our site assessment, the main stream channels had low to moderate flows, while tributary channels were flowing intermittently.

5.0 INDIVIDUAL STREAM RECONNAISSANCE OBSERVATIONS

5.1 Godman Creek

5.1.1 Upstream of the Upper Levels Highway

The mainstem of Godman Creek was traversed from near its headwaters to the Upper Levels Highway, a distance of approximately 880 m. This entire drainage is within the proposed development area.

At the approximate headwaters of Godman Creek the channel is shallowly incised (less than 0.3 m) and 0.5 to 1.0 m wide with a stream gradient of about 20 to 30 %. Adjacent native slope gradients are about 30 to 40 % with no apparent stability concerns. Upstream from here the stream is ephemeral in nature. Dense till, approximately 1 m thick, directly overlies bedrock exposed in the streambed. Progressing downstream to the Eagle Lake access road, the channel morphology is mainly bedrock-controlled with multiple channels either underlain by smooth bedrock surfaces or descending via a series of bedrock cascades. Channel gradients range from 20 to 45 %, but locally reach 55 %. Left[1] channel sidewalls are reasonably well-developed averaging about 5 to 7 m long with slopes of 40 to 80 % to the top-of-bank. Right channel sidewalls are generally less well-developed and, in places, provide poor channel confinement (less than 0.5 m). Some potential for channel avulsion and resulting erosion is considered to exist in these specific areas.

At the Eagle Lake access road, stream flow is conveyed via a 900 mm metal pipe culvert. Downstream from there, the channel gradient is less than 10 % for about 200 m and sandy alluvial deposits comprise the immediate stream banks. The channel meanders along this low-gradient reach and, at the outside bend of

[1] By convention, left and right refer to the observer's left and right when facing downstream

meanders, undermined stream cutbanks up to 1 m in height occur within the more erodible alluvial sediments. At one bend, old filter fabric buried along the bank may provide evidence of previous efforts to stabilize the channel.

Downstream from the Eagle Lake access road to the Upper Levels Highway, the channel is largely bedrock-controlled and locally follows prominent northwest-southeast trending jointing. Stumps of large coniferous trees along the immediate edge and, locally within, the stream channel indicate past lateral channel instability, likely a result of timber harvesting that extended to the streambanks. Channel gradients range from 20 to 46 %, while adjacent native slopes have similar gradients and no apparent stability concerns. Sidewalls are mainly composed of bedrock with slopes ranging from 10 m long at 30 %, to 3 m long at 150 % to the local top-of-bank. At the Upper Levels Highway, streamflow is conveyed via a single 1600 mm metal pipe culvert.

5.1.2 Western Tributary

The western tributary of Godman Creek was traversed for a distance of approximately 715 m from its headwaters adjacent to the paved Eagle Lake access road to its confluence with the main channel of Goldman Creek.

The tributary has a relatively low channel gradient (5 to 15 %) for the first 300 m where it flows along the upslope side of the Eagle Lake access road. The channel is 0.5 to 1 m wide with streambanks comprised of till. Left sidewall slopes extend for about 8 to 14 m at 22 to 40 % to the top-of-bank, while the fillslope of the Eagle Lake access road forms the right sidewall slope. Downstream from there, the stream is incorporated into the ditchline of the Eagle Lake access road. The stream/ditchline continues for a further 270 m, then is conveyed under the road via an 800 mm metal pipe culvert. This culvert discharges into a small wetland area. The stream channel reappears about 130 m downstream where it joins Godman Creek in a meandering reach of the main channel.

5.1.3 Downstream of the Upper Levels Highway

On the south side of the Upper Levels Highway, Godman Creek flows through an 1800 mm pipe culvert and then along a natural channel through Westridge Park for a distance of about 150 m. From there it proceeds downstream through a number of residential properties before discharging to Burrard Inlet. A 1500 mm concrete culvert conveys the stream under Westridge Avenue, while further downstream a 1400 mm metal pipe culvert conveys the flow under Bayridge Avenue. Near the base of slope, an arched 3500 mm pipe culvert conveys the stream under Sharon Place.

Where the stream crosses residential properties, the natural streambanks locally show evidence of past and ongoing erosion (*e.g.* 3940 Westridge Avenue and 3955 Viewridge Place). For the low gradient stream reach adjacent to properties along Sharon Place upstream of the railway crossing, the channel is either heavily aggraded with an associated decrease in streambank height, or displays significant bank erosion and undermining of locally higher sidewall slopes comprised of till. Elsewhere the streambanks are well-confined either by bedrock or by concrete retaining walls and there are no apparent erosion concerns.

5.2 Turner Creek

5.2.1 Upstream of Upper Levels Highway

The headwaters of Turner Creek have been substantively altered by the Cypress Bowl Road and, more significantly, by the District of West Vancouver's (DWV) works yard under which it appears to be contained within a buried pipe. The stream was assessed for a distance of approximately 250 m from immediately downstream of the works yard to the Upper Levels Highway. The entire stream drainage is within the area of proposed development.

Streamflow is conveyed from the works yard under the Cypress Bowl Road via a 900 mm metal pipe culvert. Downstream from the culvert outlet, the channel is about 1 m wide with a channel gradient ranging from 10 to 30 %. The channel and sidewall slopes are predominantly bedrock downstream to the Upper Levels Highway and large woody debris has locally created a number of cascades within the channel. Sidewall slopes range from about 6 m long at 40 %, to 10 m long at 65 % to the local top-of-bank. Adjacent native slopes range from 15 to 50 % with no apparent stability concerns. At the Upper Levels Highway, streamflow is conveyed via a 1200 mm concrete pipe culvert.

5.2.2 Downstream of Upper Levels Highway

On the south side of the Upper Levels Highway, Turner Creek flows through a 1400 mm pipe culvert at Westridge Avenue near its junction with Southridge Avenue. From there the stream flows in either a natural or a concrete-lined channel with no apparent erosion concerns. At 3664 Cedaridge Place, the stream is conveyed via a smaller 800 mm pipe culvert into a bedrock channel that passes under the residence on this property. Although there are no indications of past erosion or flooding at this culvert site, the limited capacity of the culvert could lead to either of these hazards. Further downstream, the stream flows either within a natural, generally stable channel or within concrete structures. At 3560 Mathers Avenue, two large concrete ponds have been constructed along the former channel. Although these ponds were reported to have been intended as habitat for waterfowl, they also likely serve to attenuate peak flows and act as sedimentation basins. Immediately downstream at 3524 Mathers Avenue, the banks of the natural channel have been protected locally with rock riprap. At this location, the eroded streambank is up to 1 m in height and exposes compact to dense glaciomarine silt. Downstream from there, the stream flows within natural or concrete-lined channels, or along road ditchlines (e.g. ditchline adjacent to 3521 Oxley Street) to Burrard Inlet with no apparent erosion concerns.

5.3 Cave Creek

5.3.1 Upstream of Upper Levels Highway

The main channel of Cave Creek was traversed from its headwaters, located approximately 300 m upstream of its uppermost crossing of the Cypress Bowl Road, a distance of approximately 800 m to the Wentworth Avenue off-ramp leading from the Upper Levels Highway. The entire drainage is within the area of proposed development.

At the approximate headwaters of Cave Creek near the base of a discontinuous 4 m high bedrock bluff, the channel is 0.3 to 0.6 m wide with a channel gradient of about 40 to 45 %. Adjacent native slope gradients are about 45 % with no apparent stability concerns. A thin (less than 0.5 m thick) veneer of sandy to bouldery colluvium directly overlies bedrock adjacent to the streambed. Sidewall slopes range from less than 3 m long at 35 %, to 7 m long at 40 % to the local top-of-bank. Approximately midway between the headwaters and the first crossing of the Cypress Bowl Road are two small zones of streambank instability. The first is a 7 m wide zone of sliding and/or slumping on the left bank that appears to have initiated as a result of discharge of concentrated surface runoff from an old logging road adjacent to the top-of-bank in this area. The landslide track is about 8 m long with a slope of about 50 %. Adjacent unaffected bank slopes are about 5 m long at slopes of about 60 %. The second zone of instability occurs about 16 m further downstream and is associated with windthrow of a large tree located on bedrock at the crest of the right bank. The windthrow resulted in exposure of some soil with subsequent erosion by the stream.

At the upper crossing of the Cypress Bowl Road, streamflow is conveyed via a 600 mm metal pipe culvert.

Between its two crossings of the Cypress Bowl Road, a distance of about 230 m, Cave Creek increases in width from about 1.0 to 1.5 m with a channel gradient that ranges from about 20 to 45 %. Adjacent native slopes display similar gradients with no apparent stability concerns. Sidewall slopes range from about 5 m long at 30 %, to 8 m long at 80 % to the local top-of-bank. The streambed and sidewall slopes are predominantly composed of bedrock overlain locally by a colluvial veneer. At the lower crossing of the Cypress Bowl Road, streamflow is conveyed via a 900 mm metal pipe culvert.

From the lower crossing of the Cypress Bowl Road to the off-ramp, a distance of about 150 m, the channel is about 2 m wide with a gradient of 10 to 60 %. The steepest reach flows along a steeply dipping (60 %) bedrock surface for a slope distance of almost 100 m. Adjacent steep native slopes show no apparent stability concerns. Sidewall slopes range from about 3 m long at 100 %, to 9 m long at 65 % to the local top-of-bank. At the off-ramp, streamflow is conveyed via a 1300 mm metal pipe culvert.

5.3.2 West Tributary

The western tributary of Cave Creek was traversed for a distance of approximately 660 m from its headwaters, located about 350 m upslope of its upper crossing of the Cypress Bowl Road, to its confluence with the main channel of Cave Creek.

In the headwaters area, the channel is about 0.4 m wide with a channel gradient of about 10 to 15 %. Sidewall slopes range from 6 m long at 18 %, to 4 m long at 25 % to the local top-of-bank. Sandy to bouldery colluvium comprises a thin (less than 1 m) veneer over bedrock.

For approximately 150 m downstream to the upper crossing of the Cypress Bowl Road, the stream follows a north-south transmission line right-of-way. Within the right-of-way, the natural stream course appears to have been disturbed by land clearing and/or access trail construction. Channel destabilization has resulted in the presence of multiple channels locally over a 10 m width. The main channel is up to 1 m in width with streambanks up to 0.8 m high within sandy to bouldery colluvium. Channel gradients range from 20 to 45 %. Sidewall slopes range from about 3 m long at 60 %, to 7 m long at 45 % to the local top-of-bank. Adjacent native slopes range from 30 to 55 % with no apparent stability concerns. A steep (100 %) bedrock slope leads to the upper crossing of the Cypress Bowl Road where a 600 mm metal pipe culvert conveys the streamflow.

Between its two crossings of the Cypress Bowl Road, a distance of about 200 m, the stream channel is predominantly bedrock-controlled with bedrock sidewall slopes ranging from about 6 m long at 45 %, to 7 m long at 60 % to the local top-of-bank. The channel is 1.5 to 2 m in width with a channel gradient of about 25 to 35 %. Adjacent native slopes range from 20 to 45 % with no apparent stability concerns. At the lower crossing of the Cypress Bowl Road, streamflow is conveyed via a 900 mm metal pipe culvert.

Downstream for about 120 m to the confluence with the main channel of Cave Creek, the western tributary is 3 to 4.5 m wide and flows along smooth, moderately sloping (50 %), bedrock . Adjacent native slopes are 45 to 62 % with no apparent stability concerns. Sidewall slopes range from 4 m long at 30 %, to 3 m long at 50 % to the local top-of-bank.

5.3.3 East Tributary

The eastern tributary of Cave Creek was traversed for a distance of approximately 380 m from its headwaters to its confluence with the main channel of Cave Creek immediately upstream of the Cypress Bowl Road.

This stream begins at the base of a broad swale and appears to be ephemeral in nature for about the first 125 m. From here to the Cypress Bowl Road, the channel increases in width from about 0.6 to 1.3 m. Channel gradients range from about 20 to 45 % as the stream crosses benchy slopes underlain by bedrock at shallow depths. Sidewall slopes range from 2 to 3 m long at 20 %, to 4 to 5 m long at 50 % to the local top-of-bank. Adjacent native slopes range from 20 to 45 % with no apparent stability concerns.

5.3.4 Downstream of Upper Levels Highway

On the south side of the Upper Levels Highway, Cave Creek is conveyed onto the immediate downstream property at 3390 Westmount Road via a 1500 mm pipe culvert. Also discharging into the stream at this location are 1200 mm and 600 mm pipe culverts, presumably carrying stormwater runoff. Within the property, the stream is initially contained in a deteriorating, concrete-lined channel with a series of 0.8 m high drop structures. Beyond this constructed channel, the stream flows within a natural channel with local erosion/undermining of the 1 m high till banks. Downstream within the properties from 3390 to 3397 Craighead Road, the stream is well-confined mainly within a bedrock notch. A smaller, 1000 mm pipe culvert conveys the stream under Mathers Avenue. Despite the apparent under-capacity of this pipe, there are no visible indications of erosion or flooding at this location. From here to its discharge point at Sandy Cove, the stream flows within either a naturally armoured channel, a bedrock or retaining wall-bound channel, or a buried pipe with no visible bank erosion.

5.4 Westmount Creek

5.4.1 Upstream of Upper Levels Highway

Westmount Creek was traversed from its headwaters, located approximately 260 m upstream of its uppermost crossing of the Cypress Bowl Road, for a distance of approximately 2,300 m to the Upper Levels Highway. The proposed development area lies immediately west of the stream above an elevation of 366 m. Below this elevation, proposed development extends both east and west of the stream.

At the approximate headwaters of Westmount Creek, the channel is poorly defined within a 5 m wide floodplain. The channel substrate consists mainly of sand and small woody debris and the channel gradient is about 30 to 35 %. Adjacent native slope gradients are about 20 to 30 % with no apparent stability concerns. Sandy to bouldery colluvium with an estimated minimum thickness of about 0.8 m is exposed locally along the stream banks. Sidewall slopes range from about 3 m long at 15 %, to 10 m long at 52 % to the local top-of-bank. At the uppermost crossing of the Cypress Bowl Road, streamflow is conveyed via a 600 mm metal pipe culvert.

Downstream to the second crossing of the Cypress Bowl Road, the stream passes through an east-west trending transmission line right-of-way with associated access road and is crossed by an old east-west trending logging road. The transmission line access road has no culvert, while the logging road has a failing wood box culvert. The channel within this reach is 1.5 to 2 m in width with a channel gradient of about 15 to 20 %. Adjacent native slopes are gentle with gradients of 12 to 20 %. Sidewall slopes range from 3 m long at 10 %, to 6 m long at 36 % to the local top-of-bank. Cutbanks, locally from 0.3 to 0.7 m high, expose sandy to bouldery colluvium. The stream flow is conveyed at the second crossing of the Cypress Bowl Road via a 600 mm metal pipe culvert.

Downstream to the third crossing of the Cypress Bowl Road, the channel is largely bedrock-controlled with a bedrock bed for most of this reach. The channel gradient ranges from 20 to 70 % as the streambed follows the stepped bedrock surface. The channel is generally shallowly incised (less than 0.5 m deep) into colluvium or till and multiple channels were noted where channel confinement is low. Channel width is up to 13 m where it flows on a planar bedrock surface. Sidewall slopes are not prominent and range from about 5 m long at 22 %, to 6 m long at 50 % to the local top-of-bank. Adjacent native slopes range from about 30 to 60 % with no evidence of instability. The streamflow is conveyed under the third crossing of the Cypress Bowl Road via a 1200 mm metal pipe culvert. The 366 m elevation (upslope boundary of proposed development in this area) is about 200 m upstream of this crossing of the Cypress Bowl Road.

Downstream to the fourth crossing of the Cypress Bowl Road, bedrock-control of the stream continues with multiple, poorly-confined channels locally developed on a planar bedrock surface. Channel gradients range from about 35 to 65 %, while adjacent native slopes are 25 to 45 %. Till is exposed along the immediate streambanks. Sidewall slopes become more prominent progressing downstream, as the thickness of the till appears to increase. Sidewall slopes increase from 3 m long at 38 %, to 10 m long at 65 % to the local top-of-bank. The streamflow is conveyed at the fourth and lowermost crossing of the Cypress Bowl Road via a 1200 mm metal pipe culvert.

Downstream from the Cypress Bowl Road to the Upper Levels Highway, the stream flows between areas of existing residential development (townhouse/condominium complexes) with a large wooden footbridge over the stream. Bedrock is exposed in the streambed, but the sidewall slopes, ranging up to 10 m at 65 %, appear to be underlain by till. Channel gradients range from about 15 to 30 %, while adjacent native slopes are about 45 % and display no evidence of instability. The streamflow is conveyed at the Upper Levels Highway via an 1800 mm metal pipe culvert.

5.4.2 Downstream of Upper Levels Highway

On the south side of the Upper Levels Highway, the stream is conveyed via a 1500 mm pipe culvert onto the properties at 3165 and 3175 Benbow Road. In this area, the stream flows within a channel bounded either by bedrock or by concrete walls with no apparent erosion concerns. The culvert at Benbow Road is a smaller, 1000 mm, pipe culvert but there is no visible evidence of erosion or flooding at this location. Downstream from here to its discharge point at Burrard Inlet, the stream flows mainly in a bedrock or concrete-lined channel with no apparent erosion concerns. At Mathers Avenue, however, there is some potential for overtopping of the banks where the channel banks are low (less than about 0.5 m at 3225 Mathers Avenue) and there is evidence of scouring at the base of a rock stack streambank retaining wall (3260 Mathers Avenue).

5.5 Pipe Creek

5.5.1 Upstream of Upper Levels Highway

The main channel of Pipe Creek was traversed from its headwaters, located approximately 275 m upstream of its uppermost crossing of the Cypress Bowl Road, for a distance of approximately 2,100 m to the Upper Levels Highway. Two tributaries (denoted as Tributary 1 and 2), located east of the main stream channel, were also traversed. The upper boundary of proposed development for this drainage occurs at the 366 m elevation.

From the approximate headwaters of Pipe Creek downstream for about 240 m, the channel is about 0.7 m wide with a sand-cobble substrate and a channel gradient of about 20 to 30 %. Dense tills are exposed locally along the streambank. The channel downstream has been locally disturbed by an old corduroy trail, which follows the streambed in places. Sidewall slopes are not well-developed ranging from about 4 m long at 70 %, to 7 m long at 35 % to the local top-of-bank. Adjacent native slopes range from about 16 to 30 % with no visible evidence of instability. At approximately 240 m downstream, bedrock forms the streambed. At the uppermost crossing of the Cypress Bowl Road, streamflow is conveyed via a 900 mm metal pipe culvert.

Downstream of the uppermost crossing of the Cypress Bowl Road, the stream initially splits into two or more channels as it descends through a broad bowl. The main channel is about 1.5 m wide with a gradient of about 20 to 30 %. Dense tills are exposed locally along the streambanks. Adjacent native slopes range from about 15 to 35 % with no visible evidence of instability. From here the stream passes through the east-west trending transmission line right-of-way with its associated access road and then crosses an old east-west trending logging road. The transmission line access road has diverted streamflow about 15 m to the west of the original channel. At the old logging road, the steam flows through a wooden box culvert with an opening about 0.6 m wide x 0.4 m high. The sill logs of this culvert show evidence of erosion/undermining. Sidewall slopes range from about 3 m long at 65 %, to 15 m long at 50 % to the local top-of-bank. Downstream from the old road crossing, the channel becomes largely bedrock-controlled with a bedrock bed. Surficial materials consist of till and, locally, sandy to bouldery colluvium. Within this reach, the stream is 1.5 to 2.5 m wide with channel gradients ranging from 25 to 50 %. Adjacent native slopes range from about 35 to 50 % with no visible evidence of instability. Sidewall slopes range from about 4 m long at 70 %, to 14 m long at 50 % to the local top-of-bank. At the second crossing of the Cypress Bowl Road, the stream flows through a 900 mm metal pipe culvert.

From the second to third crossing of the Cypress Bowl Road, the channel is weakly incised and continues to be largely bedrock-controlled with a generally planar bedrock bed. Channel gradients range from 25 to 45 %. Streamflow is commonly dispersed within multiple channels over widths up to 25 m across the bedrock surface. Colluvial soils up to 1 m in thickness are locally exposed along the immediate streambanks. Sidewall slopes range considerably from about 10 m long at 20 %, to 15 m long at 60 % to the local top-of-bank. The wide range of sidewall slopes is due to the local presence of bedrock ledges and/or knolls. Adjacent native slopes range from about 7 to 50 % with no visible evidence of instability. At the third crossing of the Cypress Bowl Road, the stream flows through a 600 mm metal pipe culvert. This pipe diameter is significantly less than the 900 mm pipe diameter present on the two upstream crossings. The upslope boundary of the area of proposed development (i.e. elevation 366 m) is about 100 m upstream of this crossing of the Cypress Bowl Road.

From the third to fourth crossing of the Cypress Bowl Road, the channel continues to be largely bedrock-controlled. Progressing downstream, multiple shallow channels with a general gradient of about 25 to 48 % become a single, well-confined 2.5 m wide channel with a gradient of about 22 to 35 % as the topography gradually takes on a more ravine-like morphology. Sidewall slopes increase from about 7 m long at 50 %, to greater than 20 m long at 80 %. Thicker till is visible in the ravine reach and is a likely factor in the degree of ravine development. Adjacent native slopes average about 35 % with no visible evidence of slope instability. Ravine sidewall slopes, as well, show no evidence of instability. At the fourth crossing of the Cypress Bowl Road, streamflow is conveyed via a 1200 mm metal pipe culvert.

Downstream from Cypress Bowl Road, the stream flows under a paved road denoted as Deer Ridge Place. The stream is conveyed under Deer Ridge Place via an 1800 mm metal pipe culvert. From here to the Upper Levels Highway, a distance of about 140 m, residential development exists above both sides of the stream. The stream channel is about 3 m wide with an average gradient of about 25 %. The stream channel is incised 3 to 5 m into till. The left sidewall slope within about 50 m of the culvert outlet has been eroded and undercut resulting in a sidewall slope gradient of about 130 % (52 degrees). This slope has previously been covered with shotcrete in an apparent attempt to mitigate further erosion. At the Upper Levels Highway, the stream flows through a 1500 mm metal pipe culvert. A steel trash rack has been installed immediately upstream of the culvert inlet.

5.5.2 Tributary 1

Tributary 1 of Pipe Creek starts on the downslope side of the third crossing of the Cypress Bowl Road by Pipe Creek. Tributary 1 lies about 35 m east of Pipe Creek at this location. The tributary was traversed downstream for about 515 m to the lowermost section of the Cypress Bowl Road. All of this stream section is within the area of proposed development. There is some existing residential development below the Cypress Bowl Road in this area.

In the headwater reach of the stream, streamflow is dispersed across a 1.5 to 5 m wide bedrock channel, which was dry at the time of our assessment. The streambanks and sidewall slopes in this area are underlain by a thin (less than 1 m thick) veneer of sandy to bouldery colluvium. The channel gradient, which ranges from 28 to 50 %, is controlled by the local bedrock surface. Sidewall slopes range from 3 m long at 30 %, to 9 m long at 65 % to the local top-of-bank. Adjacent native slopes range from 25 to 55 % with no visible evidence of instability. About 300 m downstream, the native slope and channel gradient decrease and a depositional zone about 50 m wide and about 75 m in length occurs. In this area, the channel gradient and adjacent native slopes range from 20 to 30 %. Downstream from here, the stream follows slightly steeper terrain (28 to 35 % native slopes) underlain by dense till to the off-ramp of the Upper Levels Highway. Sidewall slopes range from 6 m at 25 %, to 7 m at 60 % to the local top-of-bank. Streamflow is conveyed under the roadway via a 900 mm metal pipe culvert.

5.5.3 Tributary 2

Tributary 2 of Pipe Creek starts about 140 m upslope of the third crossing of the Cypress Bowl Road by Pipe Creek. It lies about 180 m east of Pipe Creek at this location. The tributary was traversed downstream for about 535 m to Cypress Lane.

From its approximate headwaters to its crossing of the Cypress Bowl Road, the stream channel is 0.5 to 1 m wide and the stream gradient and adjacent native slopes increase downstream from about 25 to 40 %. Bedrock is not exposed near the stream and the streambanks and immediate sidewall slopes appear comprise sandy to bouldery colluvium. Sidewall slopes range from 10 m long at 20 %, to 6 m long at 60 % to the local top-of-bank. At the crossing of the Cypress Bowl Road, streamflow is conveyed via an 800 mm metal pipe culvert. The upslope boundary of the area of proposed development is about 70 m upstream of this crossing of the Cypress Bowl Road.

Downstream for about 160 m from the Cypress Bowl Road, the channel is mainly bedrock-controlled with a locally steep (up to 60 %) channel gradient. Multiple channels occur locally where there is poor confinement adjacent to the bedrock stream bed. Sidewall slopes range from 3 m long at 40 %, to 8 m long at 32 % to the local top-of-bank. Adjacent native slopes range from about 30 to 60 % with no evidence of slope instability.

For the remaining distance (about 235 m) to Cypress Lane, colluvium and/or till underlie the stream channel and adjacent slopes. The stream is about 1.5 m wide with a gradient ranging from about 8 to 30 %. Sidewall slopes range from 4 m long at 20 %, to 5 m long at 50 % to the local top-of-bank. Adjacent native slopes range from about 18 to 25 % with no visible evidence of instability. At Cypress Lane, the stream has been diverted westward along the ditchline of this road and is then conveyed under Cypress Bowl Road near the junction of these roads.

5.5.4 Downstream of Upper Levels Highway

On the south side of the Upper Levels Highway, Pipe Creek is conveyed via a 1500 mm pipe culvert with concrete outfall and flows along the east side of the property at 3075 Spencer Court. Within this property, the left bank is retained by a concrete-rock wall that has locally been undermined by the stream. On the downstream side of Spencer Court, similar erosion has occurred along the concrete footing for a rock stack wall at 3072 Spencer Court. Downstream from here to 3088 Spencer Place, the stream flows mainly on bedrock with no erosion concerns. The stream is conveyed under Spencer Place by an 1800 mm concrete culvert. Immediately downstream of the culvert, the footings of a concrete bank retaining wall along the east side of 3074 Spencer Court are being undermined by the stream. Further downstream, the stream is conveyed under Roseberry Avenue by a 1200 mm concrete culvert. Tributary 1 has been diverted westward along the ditchline of Roseberry Avenue and flows into the same culvert. The combined stream flow is then conveyed under Mathers Avenue by a 1000 mm pipe culvert. Both of these culverts are likely undersized. At the latter location, the culvert outlet is perched and a 1 m deep scour pool occurs at the outfall. South of Marine Drive, the stream flows mainly in a large concrete-lined channel to Burrard Inlet with no erosion concerns.

6.0 GEOTECHNICAL HAZARDS ASSOCIATED WITH MOUNTAIN STREAMS

Geotechnical hazards that are typically associated with mountain streams in geographic and physical settings similar to the project site are outlined below, with specific references to particular reaches and/or locations along the surveyed streams.

6.1 Streambank Erosion

Erosion of streambanks and sidewall slopes may occur as a result of stream aggradation, channel downcutting (degradation), channel obstructions that direct flow onto erodible banks, or high flows related to extreme storm events. Aggradation may occur through a sudden input of sediment, such as when a landslide runs out to the stream channel. Factors that may lead to channel downcutting include the presence of an erodible channel substrate, high streamflow and steep channel gradients. Channel obstructions typically occur as a result of windthrown trees blocking the channel, stream deposition, landslides, or cut and fill or other construction activities extending onto the sidewall slopes and into the stream channels. Streambank erosion may lead to destabilization of sidewall slopes due to removal of toe and/or lateral support.

The localized streambank erosion observed during our field assessment appears to be associated with peak flows that are capable of transporting gravel to cobble-sized particles and generally small woody debris. Local woody debris accumulations/jams were observed in many of the stream reaches assessed and likely contributed to the observed stream erosion. Debris consisted predominantly of small woody material, much of it likely introduced as a result of breakage during the significant storm events that occurred in the winter of 2006/2007. Locally, larger woody debris accumulations were noted where windthrown trees had fallen into the channel. All the assessed streams are considered to have a relatively low water transport potential based on the observed size of accumulated debris and sediment.

Historical streambank erosion is evident at sites where past timber harvesting extended to the streambanks resulting in bank destabilization. This is most evident on Godman Creek about 250 m upstream of the Upper Levels Highway where large, still-rooted stumps occur, both within the active channel and at the former streambanks. In these areas, the streambank soils have been removed by stream erosion leaving barren bedrock surfaces. One site of bank erosion and/or instability was noted along an upper reach of Cave Creek (Section 4.3.1) likely resulted from the discharge of surface runoff from an old logging road that had not been deactivated.

Significant active bank erosion was noted in a limited number of stream reaches and appeared to be more prevalent along the downstream portions of these streams where flows are highest and streambeds and banks are more likely to be comprised of till, rather than bedrock. Large boulders weathered out from the tills may also increase bank erosion where they re-direct streamflow into the streambank. At one location on Pipe Creek between Deer Ridge Place and the Upper Levels Highway, a 4 to 5 m high, undermined till streambank has been treated with shotcrete in an attempt to mitigate further erosion and hazard to adjacent residences. The streambank erosion at this site has not resulted in any large-scale or deep instability, likely due to the generally dense nature of these tills.

In areas where multiple stream channels occur on moderately to moderately steeply dipping, planar bedrock surfaces, the potential for streambank erosion is considered to be high. In these areas, the channels are separated by thin (less than 1 m thick) remnants of colluvium or till that may be completely eroded by the stream, exposing the underlying bedrock. Increased flows due to stormwater input from the development area may accelerate this process. A high potential for streambank erosion is also considered to exist where more erodible alluvial sediments comprise the streambanks in low gradient stream reaches, such as the reach of Godman

Creek immediately downstream from the Eagle Lake access road (Section 4.1.1), where previous efforts to stabilize the eroding streambanks have been employed.

Streambank erosion along all streams, within the developed area downstream of the Upper Levels Highway, typically occurs either in areas where the natural stream channels still exist, or where older, deteriorating retaining structures do not adequately protect the streambank(s). Erosion at these sites could be worsened by increased streamflow resulting from stormwater input from the development area. The aggrading lower reach of Godman Creek upstream of the railway crossing is considered susceptible to both decreasing channel capacity and bank erosion.

6.2 Seepage Erosion

Seepage erosion occurs where groundwater discharge from relatively permeable sediments removes material from the slope face, either at the point of discharge or at a location below the discharge point. While this process sometimes occurs gradually over a period of years, occasional and rapid 'outburst episodes' may occur, which are capable of eroding significant amounts of silt and sand in a relatively short period of time. However, no areas with active seepage erosion or former seepage erosion were observed in the stream channels or ravines assessed. In general, the sidewall slopes are covered with a veneer of colluvial soils and organic forest litter that act as an effective filtration medium. This is considered to have reduced the likelihood for the occurrence of seepage erosion.

6.3 Debris Slides

Debris slides are shallow landslides that typically develop on moderately steep to steep slopes in surficial materials and initially involve sliding of a soil mass (debris slide) that may or may not change into a flow. Such landslides may initiate along stream sidewall slopes as a result of erosion/undermining of the slope by the stream. No visible evidence of previous debris slides were observed within the drainages assessed, either on the stream sidewall slopes or on the immediately adjacent natural slopes, except for the previously noted small debris slide on Cave Creek which is considered to have been road-related. We consider that such features are unlikely to develop along the stream sidewall slopes due to their generally gentle slope gradients combined with generally short slope lengths. As previously noted, well-developed long and steep ravine sidewall slopes occur locally along Pipe Creek just upslope of the Upper Levels Highway where the hazard is considered to be moderate to high. On Rodgers Creek to the east of Pipe Creek and beyond the project area, ravine slopes immediately upstream of the Upper Levels Highway are moderately to well-developed and were observed to have experienced debris slides as a result of failure of sidewall slopes.

The potential for increased debris slide and/or debris avalanche activity due to increased stream flow associated with stormwater input from development is considered to be generally low, except along Pipe Creek for about 500 m upstream of the Upper Levels Highway where the potential is considered moderate. Sediment and woody debris from a sidewall debris slide or debris avalanche in this area could potentially block the 1500 mm pipe culvert at the Upper Levels Highway, although a trash rack has been installed just upstream of this culvert, presumably to address such an event. Such an event could result in increased bank erosion.

6.4 Debris Flows

Debris flow hazards are most commonly associated with well-developed gully systems characterized by steep, unstable sidewalls and/or headwalls and steep channel gradients. Debris flows in the Pacific Northwest coastal areas involve the rapid downstream movement of saturated sediment and woody debris along a deeply-incised, well-confined, moderately steep gradient (generally greater than 50 %) stream channel. They may start as relatively small events but can quickly increase in volume as they move downstream and entrain debris. Debris flows are most commonly initiated by landslides that run out to the stream channel, or, more rarely by extreme streamflow events. Most of the stream reaches assessed are not confined by well-developed gully sidewalls and have channel gradients less than 50 % (except locally where the streams flow on moderately steep bedrock surfaces). Accordingly, we consider the likelihood for debris flows to occur on most of these streams to be low. However, Rodgers Creek to the east of the project area, has more well-developed ravine/gully sidewall slopes with a steeper (about 50 %) channel gradient in the upper part of its watershed. Large woody debris jams and local debris levees, indicating a high water transport potential on this stream, and landslides along the ravine/gully sidewalls suggest that Rodgers Creek has a moderate to high potential for the occurrence of debris flows.

We consider there to be a low potential for increased debris flow activity within the stream reaches assessed due to increased stream flows associated with stormwater input from the development area. However, as noted in Section 5.3, the potential for debris slides and/or debris avalanches along lower Pipe Creek (*i.e.*, just upstream of the Upper Levels Highway) could be increased in response to increased streamflow. Such events could potentially trigger a debris flow that could block the culvert at the Upper Levels Highway and/or result in increased bank erosion.

6.5 Human-Induced Geotechnical Hazards

Human activity may significantly influence slope stability along stream sidewall slopes. In some cases, urbanization and land use activities in the Lower Mainland have substantially aggravated natural slope processes, or have compromised slope stability. Some human activates affecting slope stability include:

- Vegetation removal from slopes may result in loss of soil reinforcement, increase seasonal soil moisture, and increase erosion, which may act to destabilize the near surface soils. Specifically, past timber harvesting within the project area commonly extended to the stream banks resulting in localized areas of bank destabilization. Small, open slope debris slides noted on 1954 aerial photographs in the Westmount and Pipe Creek drainages may be associated with former logging activities.
- Collection, concentration, and uncontrolled discharge of upland runoff may result in soil erosion, increased peak runoff, and associated stream channel and bank erosion. Unmanaged stormwater runoff from abandoned logging roads and trails in and adjacent to the project area may contribute to stream channel and bank erosion, or may contribute to reduced slope stability if the runoff discharges onto steep, potentially unstable terrain.
- Placement or disposal of non-engineered fills along or below slope crests may result in overloading of natural slopes, or changes in drainage patterns on the slope, and may instigate slope movement.

7.0 DISCUSSION AND RECOMMENDATIONS

Based on the results of this assessment, we consider that all of the streams assessed have the potential to be adversely affected to varying degrees by increased streamflow due to stormwater input from the proposed development area. Adverse effects might consist of:

- Increased bank erosion where the streambanks are comprised of colluvium or till and the streambed is underlain by a relatively smooth bedrock surface, or where the streambanks are composed of more erodible materials such as alluvial sands. Locally within the developed area downslope of the Upper Levels

Highway, increased bank erosion, channel aggradation and undermining of streambank retaining structures are considered possible.

- Increased water transport of sediment and debris could result in blockage of culvert inlets, especially those culverts that may be undersized with respect to upstream culverts.
- Locally, there may be increased potential for debris slides and/or debris avalanches from some ravine/gully sidewalls. Such events may result in increased bank erosion, blockage of culverts or, less likely, initiation of debris flows.

It is generally recommended that direct discharge of stormwater runoff from the proposed development area to stream channels be avoided. However, erosion mitigation works carried out along the identified high risk stream sections may allow for direct discharge of stormwater. It is recommend that a comprehensive hydrologic review of the drainage area be completed to determine if existing culverts require upgrading and what adverse effects might arise within private properties crossed by the streams.

Past timber harvesting and road/trail construction has occurred throughout the site. In places, wood culverts on the assessed streams are failing due to erosion of the footings or due to collapse of the superstructures. We recommend that consideration be given to properly deactivating all old logging roads including the removal of all such stream crossing structures and restoration of the natural stream channels at these sites.

The presence of shallow bedrock and dense, relatively low-permeability surficial sediments (till) within the overall development area, and also within the banks of local streams, is considered a significant natural constraint for infiltrating stormwater using either localized structures (*i.e.*, centralized detention) or distributed approaches (*i.e.*, infiltration trench network). Increasing the overall rate and/or volume of stormwater infiltration within the development area will also be significantly constrained by the relatively thin profile of the surficial sediments available to receive, store and transmit stormwater. However, on an annual basis, there will be increased opportunity for subsurface storage and infiltration of stormwater when the unsaturated sediment profile is typically greatest, during the period of late-spring to early-autumn.

It is also recommended that designated wetlands, such as those associated with the Godman Creek system (Section 4.1.2), be further considered as potential detention areas for stormwater originating from the development area. The feasibility of utilizing a particular wetland for stormwater management purposes would necessarily require that a hydrologic review by undertaken to specifically examine the hydraulic capacity of the wetland(s). Further, the ecological function of each prospective wetland detention area would need to be examined to assess the potential impacts of introducing urban quality stormwater into the wetland system(s). It is probable that the Canadian Department of Fisheries and Oceans would require additional assessment of potential impacts on resident fish (*e.g.*, cutthroat) populations, where wetlands discharge directly into fish-bearing streams.

8.0 CLOSURE

We trust that the information contained within this letter is sufficient for your current requirements. Should you have any questions, or require clarification of any descriptions or recommendations outlined above, please do not hesitate to contact us.

Yours truly,

GOLDER ASSOCIATES LTD.

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RW/MGG/MM/tk

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Associated Engineering and Jacques Whitford AXYS Ltd. 2008. *Rodgers and Marr Creeks Integrated Stormwater Management Plan.* Draft Report to District of West Vancouver, February.

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Kerr Wood Leidal Associates Ltd. 2002. *McDonald and Lawson Creeks Integrated Stormwater Management Plan.* Report to District of West Vancouver. KWL File No. 409.014, December.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

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The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (cont'd)

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

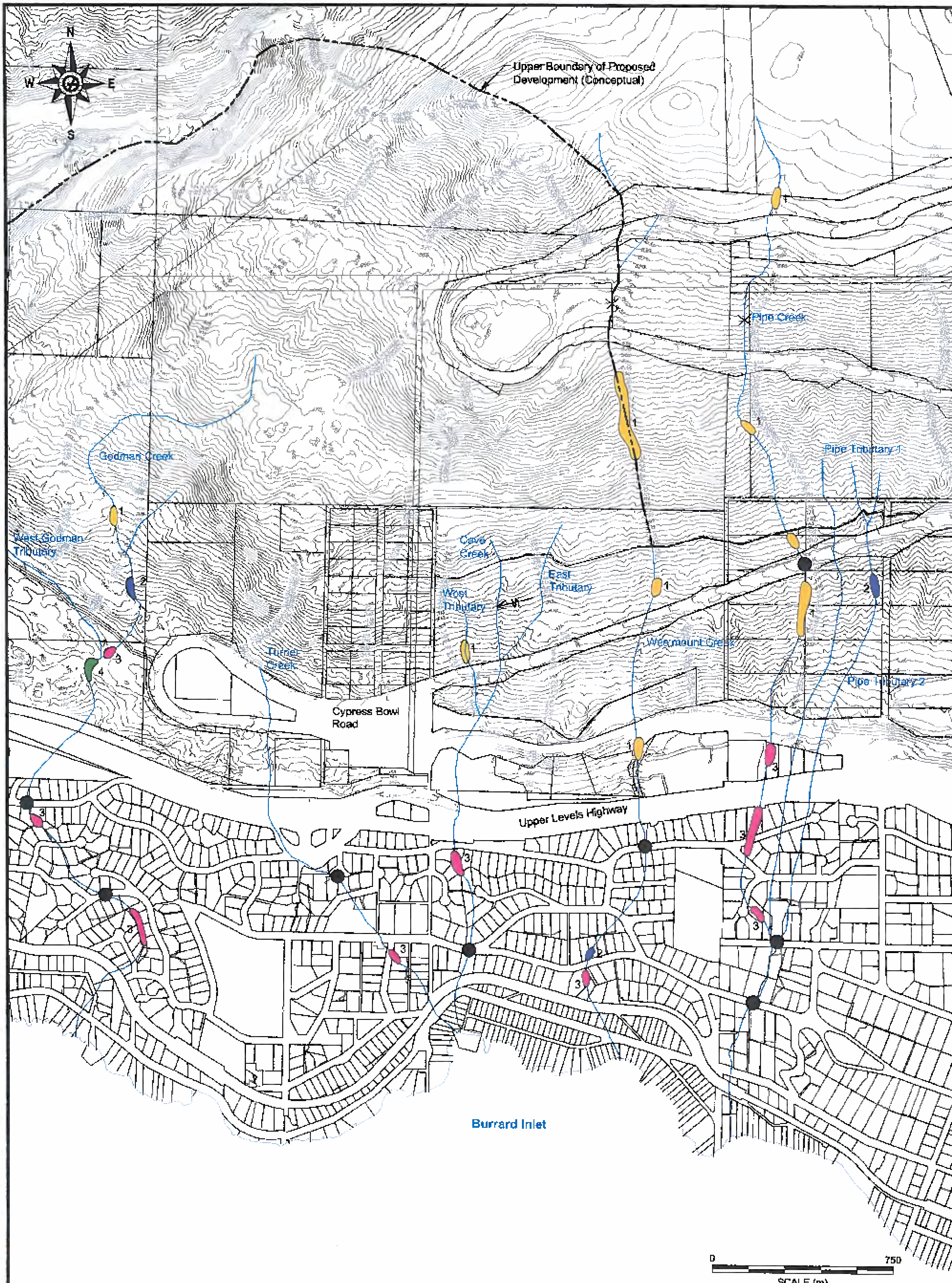
Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.



LEGEND

- 1 — Potential for Erosion Where Stream Flow is Contained in Multiple Channels.
- 2 — Potential for Avulsion and/or Flooding Due to Poor Channel Confinement.
- 3 — Erosion of Natural Banks or Undermining of Constructed Walls Along Stream Bank.
- 4 — Previous Channel Destabilization (Likely Due to Logging)
- ● Culvert Likely Undersized
- × Failing Wood Culvert
- Sidewall/Bank Failure

PROJECT
DAYTON AND KNIGHT
GEOTECHNICAL STREAM ASSESSMENT
WEST VANCOUVER

TITLE
SITE PLAN

Golder Associates
Abbotsford, BC

PROJECT	No. 08-1411-0126	PHASE	1000	TASK	3000
DESIGN	R.W.	OCT-15-08	FILE No.	P0814110126-02	
CADD	D.T.	NOV-04-08	SCALE	AS SHOWN	REV. 0
CHECK	R.W.	JAN-26-09			
REVIEW	M.G.	JAN-26-09			

FIGURE 2

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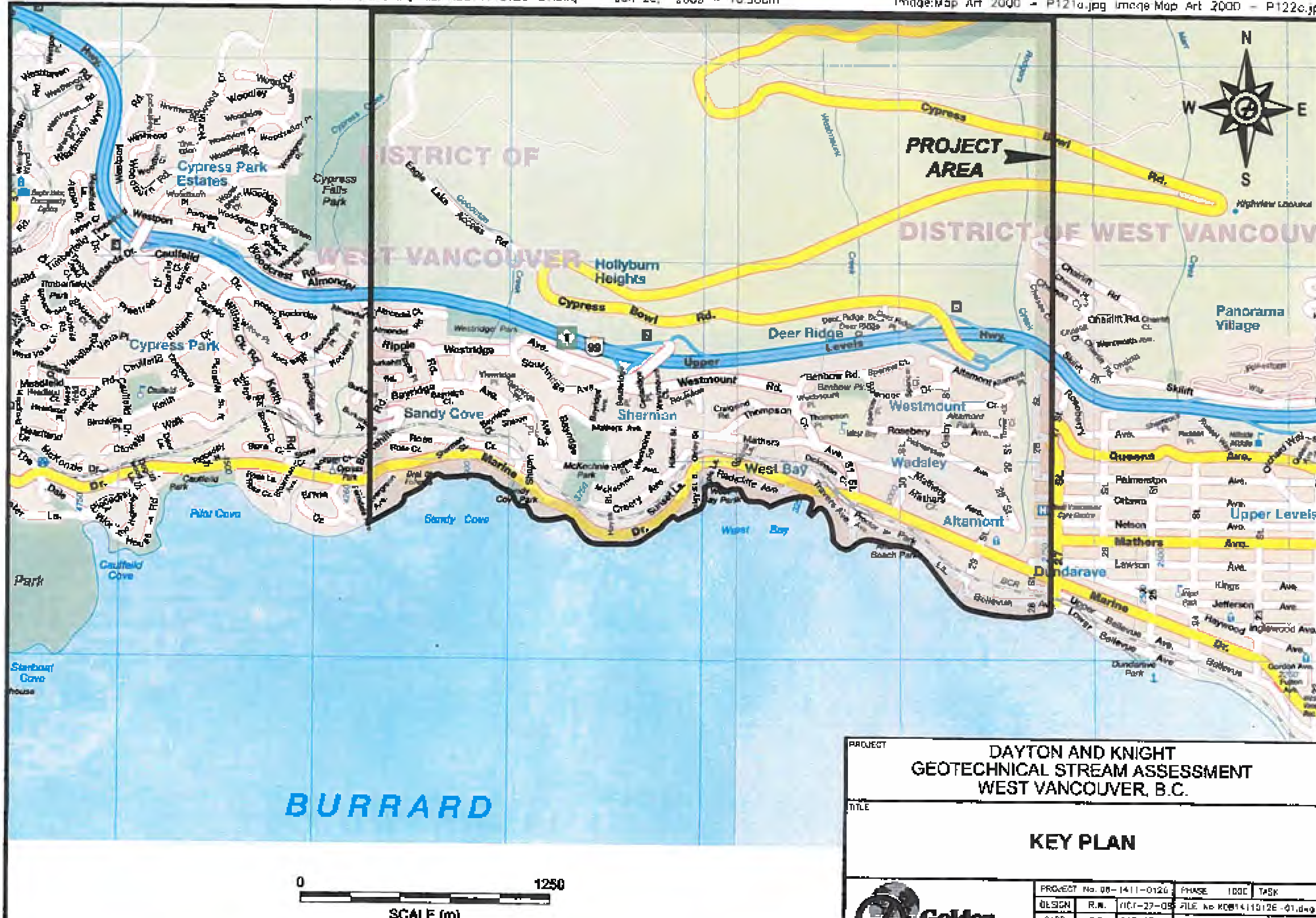

PROJECT

DAYTON AND KNIGHT
GEOTECHNICAL STREAM ASSESSMENT
WEST VANCOUVER, B.C.

TITLE

KEY PLAN

Golder Associates
Abbotsford, BC

PROJECT No. 08-1411-0126			PHASE 1000	TASK
DESIGN	R.W.	OCT-27-08	FILE No. K0814110126-01.dwg	
CADD	D.T.	OCT-27-08	SCALE AS SHOWN	REV. 0
CHECK	R.W.	JAN-26-09	FIGURE 1	
REVIEW	M.S.	JAN-26-09		

APPENDIX I

TRAVERSE TABLES

GODMAN CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
Godman Mainstem	0m	0.5-1 /30-20	30-40	3 @ 45	7 @ 55	POC at approx. headwaters, traversing downstream. Dense sandy till exposed in 1 m high cutbanks and channel directly overlies bedrock. Minimal flow.
	75m	1/25-45	15-40	6 @ 25	7 @ 50	Multiple channels over 40m width with weathered bedrock bed. Main channel is 1 m wide with 1.2m high vertical banks in till (3 other relict or ephemeral channels).
	120m					Small dry channel enters on right.
	150m	1.5/25-35	30-45	7 @ 35	6 @ 8 5 @ 80	0.4m high cutbanks in till.
	173m					Small channel enters on left.
	250m	3/20-25	20	0.3 @ 150	8 @ 45	Right bank has poor confinement – high risk for avulsion.
	270m					Trail crossing
	282m	4/22-55				Crest of bedrock cascade (55% downstream gradient)
	310m					Bedrock stream bed with less than 0.3m confinement locally
	328m					Accumulation of medium woody debris and boulder debris at base of cascade.
	350m	1.5m/15-15	23-50	1 @ 150 9 @ 60	8 @ 40	Right bank has 1m high bedrock bank. Small to medium woody debris accumulations in channel.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	380m					Compact to dense Fe-stained colluvium bank up to 1 m high; overlies bedrock in channel.
	402m	/17-20				Trail crossing
	450m	0.5-1/23-40	20-28	9 @ 75	2 @ 150 7 @ 65	Bedrock sidewalls; stream flows well confined in bedrock notch
	500m					900mm CMP conveys flow under paved Eagle Lake access road. Downstream from road stream gradient is gentle (<10%). GPS at road c/l: 483643E/5466466N
	556m	1.5/5				Bend in stream with bank undermining ~ 1m high in sandy erodible alluvium; evidence of past efforts to repair banks.
	575m					Confluence with West Tributary
	580m	3/5-10	5	10 @ 25	3 @ 45	Cutbanks are 0.3-0.5m high
	610m					Bedrock adjacent to left bank
	657m					Creek bends to ~310° following prominent jointing in bedrock. Large stump on edge of channel – channel has been destabilized by logging of banks. Local jams of small woody debris.
	680m	3/26-28	20	4 @ 50	2.5 @ 150 (rock) 7 @ 60	Bedrock-controlled channel.
	700m					Left bank has 1-2m high cutbank in dense till.

GODMAN CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	715m					Channel widens to 8m with large stumps in centre of channel (destabilized).
	785m	6/20-30	20-40	11 @ 25 3 @ 150 (rock)	10 @ 30	Bedrock stream bed, bedrock controlled channel.
	850m		50			Crest of moderate bedrock slope leading to Upper Levels Highway.
	860m	2/46-40	40	3 @ 75	5 @ 70	Bedrock channel and banks. Chain link fence.
	870m	/100 ds				Steep drop to highway on bedrock.
POT	880m					Inlet of 1600mm CMP at Upper Levels Highway.
POC Godman West Tributary	0m	<0.5/5	10 above RB 45 above LB	6 @ 36	>30 @ 45	Headwaters of tributary immediately north of Eagle Lake access road. GPS 483143E/5466900N Dry channel with organic substrate within 11m wide valley bottom.-
	100m	0.7/20-12	10 above RB 60 above LB	17 @ 65	14 @ 30	No erosion or stability concerns.
	200m	1/8-15	"	5 @ 48 4 @ 20 10 @ 60 (road fillslope)	3 @ 40	Sandy till exposed in stream bed. Cutbanks 0.3-0.5m high.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	300m	0.5-1/30-10	15 above RB 50 above LB	8 @ 25	8 @ 22	
	330m					Stream is contained within ditchline of Eagle Lake access road.
	400m	0.7/12	28-38	1.5 @ 75	1.5 @ 150 4 @ 50	Road cut is within bouldery colluvium/till. Right bank/road shoulder is locally undermined and failing.
	500m	0.8/7	15-20	1.5 @ 80	3 @ 80	Right bank/road shoulder locally undermined.
	568m					800mm CMP conveys flow under Eagle Lake road. Creek enters low gradient wetland area. No sidewall slopes.
	715m					Confluence with mainstem in area where mainstem banks are undermined.
Downstream from Upper Levels Highway						
Westridge Park	From outlet of 1800mm pipe culvert at ULH, the stream flows in a natural channel through Westridge Park. Stream is crossed by park trails and footbridges. At uppermost crossing, the sill logs from old wood culvert remain; 1.3m span with no erosion of sills. Further downstream, bedrock forms stream bed with 2.5m wide channel; some undermining of 0.4m high colluvial banks.					
3941 Westridge Avenue	From Westridge Park, the stream flows through property at 3941 Westridge Avenue. Stream channel is either well-confined by bedrock or by retaining walls. Freeboard has been increased where retaining walls occur. No erosion concerns.					
3940 Westridge Avenue	1500mm concrete culvert conveys flow under Westridge Avenue. Within property at 3940 Westridge Avenue, stream flows in natural 3m wide channel that has been riprapped where previous bank undermining occurred. Riprap shows evidence of displacement due to ongoing erosion.					

APPENDIX IA
GODMAN CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
3955 Viewridge Place		Stream flows in natural channel with outside bank eroded and undermined; cutbank about 1m high with boulders from till deposited in stream. Boulders may exacerbate bank erosion during high flows.				
3950 Viewridge Place		Along northern half of property, stream has concrete-rock or rock stack retaining walls along banks. On southern half of property, stream is confined within incised bedrock channel. No erosion concerns.				
3985 Bayridge Avenue		In this area the stream bends to the southeast and runs parallel to Bayridge Avenue. Steep bedrock channel with waterfall; small debris jams at base of waterfall. Channel is 5m wide with banks of bedrock or concrete retaining wall. Bedrock commonly forms stream bed and concrete weir structures have been constructed locally.				
Jct Bayridge Avenue/ Bayridge Court		1400mm pipe culvert conveys flow across road about 60m east of junction.				
3920 Bayridge Avenue		Stream flows along east side of this property. Near vertical bedrock stream banks/sidewalls about 3m high occur downstream of culvert. Channel further downstream is wide and stepped down on bedrock. Low gradient reach starts at south end of property.				
3924/3916 Sharon Place		Channel gradient is <5%; channel is heavily aggraded with eroded/undermined banks up to 0.7m high in till. Aggradation has reduced freeboard locally. Wood sills have been embedded across channel likely to enhance fish habitat (lots of fish present).				
3908 Sharon Place		Steep sidewalls in till are up to 4m high. Riprap placed along toe of undermined right bank has not prevented scour. Riprap along upper portion of left bank is failing. Undermined trees along top-of-banks may topple into stream. Arched 3500mm pipe culvert conveys flow under Sharon Place. Upstream of culvert inlet the left bank has been retained/protected with DeltaLock wall. Downstream from culvert the channel is 2m wide with no evidence of erosion.				
4013/4014 Rose Crescent		On south side of railway tracks, stream flows within 3m wide x 1m deep concrete channel. No erosion concerns.				
4025 Marine Drive/ 4020 Marine Drive		Stream flows either within concrete channel or within natural 1.6 m wide channel that has been riprapped; discharges to beach.				

POT

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APPENDIX IB
TURNER CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
Turner	0m					POC: approx. headwaters of creek has been altered by Cypress Bowl Road and works yard. Flow has been conveyed under works yard via buried pipe. Traverse downstream from outlet of 900mm CMP on downslope side of Cypress Bowl Road.
	25m	1/10-6	15-40	8 @ 40	8 @ 60	Large woody debris has created series of cascades. Crest of right bank in bedrock.
	50-90m	30-45 ds				Mainly bedrock banks.
	100m	1/20-10	22-30	5 @ 25 10 @ 65 (rock)	6 @ 40	Above left bank is fillslope of adjacent development.
	130m					Bedrock stream bed.
	200m	1/25-30	50	10 @ 30	10 @ 50	Directly under transmission line. Cutbanks 0.6m high. Crest of left bank in bedrock.
	232m	70 ds to ULH				Chain link fence.
	250m					Inlet of 1200mm concrete culvert at Upper Levels Highway. GPSD at road shoulder: 484043E/5466024N

Downstream from Upper Levels Highway

Jct Westridge Avenue/ Southridge Avenue	Stream discharges through 1400mm pipe culvert on south side of Westridge Avenue near junction with Southridge Avenue. Channel is concrete- lined downstream from culvert. Stream is then conveyed under Westmount Road with pipe culvert. Downstream from Westmount Road, natural channel is 1.5-2m wide and incised up to 0.8m into till with local bank undermining. Wooden trash rack at inlet of culvert under Cedaridge Place.
3660 Cedaridge Place	Stream has concrete-rock retaining walls along banks. Channel about 1m wide x 0.8m deep. No erosion concerns.

APPENDIX IB
TURNER CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
3664 Cedaridge Place		Stream conveyed under driveway of residence by 800mm pipe culvert. Downstream from culvert, stream has bedrock bed and banks and flows under residence. Limited freeboard along channel (<0.5 m locally). Stream gradient increases to about 50% downstream from residence. No erosion concerns.				
3601 Mathers Avenue		Natural channel with good confinement and large boulders lining banks. Retaining walls have been constructed along banks; terraced ponds constructed near south end of property. No erosion concerns.				
3560 Mathers Avenue		Property has two large concrete ponds with weir overflows. These structures likely help to attenuate peak flows and also serve as sediment basins.				
3524 Mathers Avenue		Stream flows in natural 1.5m wide channel but banks have been riprapped locally. Near the southern end of the property, the undermined stream bank is about 1m high within glaciolacustrine silt.				
466 Hillcrest St		Stream flows on bedrock then into channel with concrete-rock retaining walls along banks.				
Jct Creery St/Oxley St		Stream flows on bedrock through 3521 Oxley St, reappears along ditchline of Oxley St. Ditch channel is 1.3m wide x 0.75m deep; banks consist of stacked riprap. No apparent erosion concerns.				
Downstream of Marine Drive		Stream flow conveyed to beach in channel that is partially concrete-rock lined. No erosion concerns.				

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APPENDIX IC
CAVE CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
Cave Mainstem						POC: approx. headwaters of mainstem upslope of lower section of Cypress Bowl Road.
	126m	0.3/32-24	35	3 @ 30	6 @ 40	Dry channel, low water transport potential.
	161-186m	45 ds				Bedrock stream bed.
	226m	1/40-23	40	7.5 @ 40	7 @ 40	Left bank in bedrock at 246m.
	320m	1.5/36-32	40	9 @ 30	4.5 @ 35	Stream bed locally on bedrock.
	340m					Inlet of 600mm CMP at Cypress Bowl Road.
	356m					C/L of Cypress Bowl Road GPS: 484689E/5466422N
	390m					Toe of large rock fillslope of Cypress Bowl Road.
	404m	1/20-25	25	5 @ 30 1.5 @ 150	3 @ 50	Thin colluvium over bedrock.
	438m					Bike trail
	464m					Bedrock stream bed.
	483m	40 ds				Bike trail
	506m	1.5/35-40	25-35	2 @ 100 5 @ 55	6 @ 35	Stream bed and right bank in bedrock.
	542m	45 ds				Left bank and stream bed in bedrock.
	559m	2/60-45	45	6 @ 45	8 @ 80	"
	578m					Inlet of 900mm CMP at Cypress Bowl Road.
	591m					C/L of Cypress Bowl Road GPS: 484612E/5466211N
	616m					Toe of rock fillslope.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	648m	1.5-2/60-50	55	3 @ 100	5 @ 60	Bedrock stream bed.
	701m					"
	726m	2/23-14	15	16 @ 45	9 @ 65	Boulder-cobble substrate.
	770m	10 ds				Bedrock stream bed.
	786m	40 ds		2 @ 100	2 @ 100	Chain link fence. Bedrock stream bed, sidewalls are colluvium over rock.
	803m					Inlet of 1300mm CMP under off-ramp of Upper Levels Highway.
	810m					C/L of off-ramp. GPS: 484586E/5466011N
						North side of Upper Levels Highway. GPS:484493E/5465975N
Cave West Tributary	0m	0.4/10-15	15-20	4 @ 25	6 @ 18	POC: approximate headwaters of tributary. Sandy substrate with minimal flow. Thin (<1m) colluvium over bedrock.
	30m					Dry ephemeral channel enters on right. Bedrock sidewall.
	50m					Bedrock on left bank.
	100m	1.5-2/20-25	30	7 @ 35	5 @ 38	Channel has eroded through bouldery colluvium to bedrock.
	135m					Bedrock stream bed.
	146m					Channel is directly under transmission line RoW.
	180m	1/35-20	30-55	3 @ 60	7 @ 15	Within transmission line RoW.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	293m	/34-45	30-40	5 @ 20	7 @ 45	Multiple (3) channels over 10m width. 0.8m high cutbanks in bouldery colluvium. RoW clearing may have destabilized stream banks.
	325m		45			Bedrock at surface; slope increases from 45% to 100% immediately upslope of Cypress Bowl Road. 600mm CMP at Cypress Bowl Road.
	346m					C/L of Cypress Bowl Road. GPS: 484464E/5466373N
	367m					Toe of rock fillslope.
	412m	1.5-2/25-35	20-35	5 @ 70	7 @ 60	Right bank in bedrock. Boulder substrate in channel.
	444m					New bridge on bike trail. Bedrock on both sidewall slopes.
	485m					Cross washed out old road.
	500m	2/35	35-45	6 @ 45	8 @ 40	Boulder substrate.
	514m	55 ds				Steep stream gradient in bedrock to ditchline of Cypress Bowl Road.
	538m					Inlet of 900mm CMP. C/L of Cypress Bowl Road GPS: 484562E/5466206N (approximately 50m west of Cave mainstem crossing).
	578m					Toe of rock fillslope.
	600m					Bedrock stream bed.
	615m	4.5/50	45-62	4 @ 30	3 @ 50	Wide channel with low incision on bedrock.
	660m					Confluence with mainstem of Cave Creek. POT

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
Cave East Tributary	0m	0.3/43	45	8-10 @ 45	20 @ 45	Ephemeral flow within poorly defined channel at base of broad swale.
	125m	0.6/40-35	45	5 @ 20	8 @ 35	
	156m	0.6/45-20	45-20	<3 @ 10-40	<3 @ 10-40	General toe of slope.
	200m		20			C/L of old road; stream flow is diverted to southeast along road for 40m.
	240m	0.8/20	20	2-3 @ 20	2-3 @ 20	Flow diverted by road re-enters original channel.
	277m	0.8-1.2/30	30	3 @ 20-50	4-5 @ 50	Stream crossed by bike trail/bridge.
	315m	1.0-1.3/28-40	40	3 @ 45	5 @ 45	Bedrock at top of both banks.
	380m					Confluence with mainstem at inlet of culvert at Cypress Bowl Road. POT
Downstream of Upper Levels Highway						
3390 Westmount Road	Stream is conveyed to this property via a 1500mm pipe culvert. At the outlet of this culvert, there are also 1200mm and 600mm culverts discharging into the stream. Downstream, stream flows within old concrete-lined channel (3.5m wide x 0.3 to 0.5m deep) in generally poor condition with potential for wall failure. Channel has a series of incorporated drop structures up to 0.8m high. At southeast corner of property, the channel is natural (2m wide x 1 m deep) with local bank undermining; gravel-boulder substrate with till banks.					
3390-3397 Craighead Road	Stream flows within well-confined bedrock notch. No erosion concerns.					
3465 Mathers Avenue	Upstream side of road. Stream flows along east side of this property initially within bedrock notch then along boulder-lined natural channel to 1000mm pipe culvert under Mathers Avenue (NB. likely undersized compared to inflow at 3390 Westmount Road). Two stormwater runoff pipes also discharge here. No apparent erosion concerns.					
3399 Thompson Crescent	Stream flows along west side of this property. Existing residence has minimal setback from top-of-bank. Large rock lines the channel and there are no apparent erosion concerns.					

APPENDIX IC
CAVE CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
3440-3460 Mathers Road		Stream channel is bounded by bedrock or by concrete retaining walls with incorporated concrete weirs. No erosion concerns.				
Downstream from Marine Drive		Stream conveyed to Sandy Cove within buried pipe.				

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WESTMOUNT CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
Westmount	0m	1 /35-30	20-30	10 @ 52	3 @ 15	POC at approx. headwaters, traversing downstream. Sandy substrate, poorly defined channel. Locally up to 0.5 m high cutbank.
	100m	2/20-40	30-45	8 @ 30	10 @ 30	Lots of small woody debris in channel (low water transport potential). Locally up to 0.5 m high cutbank in bouldery colluvium.
	200m	2/35-25	25-40	6 @ 62	15 @ 10 8 @ 52	Poorly defined channel within 5 m wide floodplain
	250m					Inlet of 600mm CMP at upper crossing of Cypress Bowl Road.
	260m					C/L of Cypress Bowl Road
	370m	1.5/20-20	12-15	0.7 @ 150 5 @ 10	0.7 @ 150 6 @ 15	Up to 0.7 m high near-vertical cutbanks in colluvium.
	410m					C/L of powerline. Access road crossing has no culvert.
	470m	1.5/15-20	14-20	5 @ 25	5 @ 5 6 @ 36	Up to 0.3 m high cutbanks locally. 490m – small tributary enters on right.
	510m					Old road crossing with undersized failing wood box culvert.
	565m	2/20-40	16-18	3 @ 34	3 @ 10	567m – inlet of 600mm CMP at second crossing of Cypress Bowl Road.
	575m					C/L of Cypress Bowl Road

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	670m	2/30-20	17-25	3 @ 40	5 @ 25	Locally bedrock channel, stream profile is bedrock-controlled. 720m – slopes steepen to >40% (colluvial venner over bedrock)
	770m	2/47-65	40	2 @ 75	<1	High avulsion potential due to low channel confinement on bedrock. Multiple channels locally.
	795m	/50-35				Channel splits.
	870m	2/35-30	30-34	7 @ 30	7 @ 30	Local 0.3m high cutbank – no erosion concerns. 887m – 4-5m high bedrock waterfall 905m – 53% downstream, follows jointing 940m – 70% downstream on rock
	970m	13/50-50	50	4 @ 50	6 @ 40	Channel poorly confined over 13m width on bedrock
	1070m	10/35-35	30-40	4 @ 36	6 @ 50	Bedrock channel, poorly confined. 1100m – good confinement starts (sidewalls are 6-10m @ 30-40%)
	1170m	1/20-20	28-34	4 @ 28	6 @ 36	Single channel here. 4m wide floodplain on left bank.
	1190m	55 ds				Crest of bedrock ledge.
	1250m	22 us				Old road crossing.
	1258m	70 ds				Crest of another bedrock ledge with steep face for 12m.
	1270m	4/60-30	60	7 @ 50	3 @ 30	Bedrock channel continues
	1370m	10/45-38	32-40	4.5 @ 50	5 @ 22	Braided channel on bedrock

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	1480m					C/L of Cypress Bowl Road; 1200mm CMP conveys flow.
	1582m	1.5/35-45	25	7 @ 35	3 @ 38	Locally bedrock channel.
	1682m	4/65-30	38-45	10 @ 65	6 @ 55	
	1975m	7/50-60	40-45	4 @ 50	5.5 @ 50	Bedrock channel – dispersed flow.
	1988m					Crest of steep bedrock cut above Cypress Bowl Road.
	2003m					Inlet of 1200mm CMP
	2013m					C/L of Cypress Bowl Road.
	2089m					2m high bedrock ledge; 3 channels disperse flow across 12-15m
	2100m	16/30-30	45-50	6 @ 40	4 @ 50	Multiple channels over 16m width
	2130m					Footbridge behind apts.
	2192m	2/20-15	45	10 @ 65	6 @ 40	
	2243m					Bedrock continuous to 1800mm CMP at Upper Levels Highway at 2270m.
Downstream from Upper Levels Highway						
3165/3175 Benbow Road	Stream conveyed from Upper Levels Highway via ~1500mm pipe culvert; stream runs along common boundary of properties for much of the way. Channel is mainly bedrock with concrete-rock retaining wall along right bank and concrete retaining wall along left bank with 1.5m freeboard on outside bend of stream. No erosion concerns. Culvert at Benbow Road is 1000mm pipe.					
3185 Benbow Road	Right bank of stream is bound by concrete foundation of residence. Left bank is natural (mainly bedrock). Bedrock also forms stream bed. No erosion concerns.					
3235 Thompson Place	Well confined bedrock channel. No erosion concerns.					

APPENDIX ID
WESTMOUNT CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
3125 Mathers Avenue		Concrete retaining walls along banks with 1m freeboard. No erosion concerns.				
3225 Mathers Avenue		Bedrock channel but limited freeboard (<0.5m); banks are supported by concrete-rock retaining walls. Potential for flooding of lawn area downslope of residence where freeboard is lowest.				
3260 Mathers Avenue		Portion of bank retaining wall is stacked rock with evidence of scour/erosion at base.				
3285 Marine Drive		Stream is contained within concrete channel (2.3m wide x 0.6m high) that is located under residence. Adequate channel capacity, no erosion concerns.				
3274 Marine Drive		Stream is conveyed by buried pipe along west side of property with discharge to beach. No erosion concerns.				
		POT				

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PIPE CREEK TRAVERSE TABLE

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
Pipe Creek mainstem	0m	0.7/20	16-20	5 @ 20	4 @ 38	POC: approximate headwaters of mainstem. Channel has sand-cobble substrate; low water transport potential, gentle sidewall slopes.
	100m	0.8/25-32	25-30	4 @ 32	4 @ 70	0.5m thick topsoil overlies dense tan-coloured till. No erosion or stability concerns.
	180m					Start of old corduroy trail which subparallels stream.
	200m	/25-20	25-35	6 @ 25	5 @ 52	Channel is braided due to disturbance by trail.
	240m	1/15-10	30	3 @ 15 7 @ 35	5 @ 15 7 @ 35	Bedrock stream bed.
	266m					Inlet of 900mm CMP at Cypress Bowl Road.
	275m					C/L of Cypress Bowl Road GPS: 485381E/5467266N
	307m					Toe of rock fillslope.
	335m	1.3/25-35	30-35	3 @ 65	4 @ 75	Two channels with 0.5-1.0m high cutbanks. Main channel is 1.3m wide.
	358m					Cross bike trail; start of wide bowl area.
	385m					Two channels over 25m wide floodplain.
	408m					Old trail. Three channels over 25m width – one active, two ephemeral.
	440m	1.5/30-20	17-33	5.5 @ 25 4.5 @ 60	10 @ 40	Cutbanks <0.3m high.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	448m					Transmission line access road on bedrock; diverts stream flow to west by about 15m.
	452m					Centre of transmission line RoW.
	480m					Bedrock stream bed.
	500m	2-2.5/45-25	15-35	15 @ 50	8.5 @ 40	Well-defined sidewall slopes. Bedrock at crest of right bank. 0.3-0.5m high cutbanks.
	588m	35-40 us				C/L of old road. Wood box culvert (0.6 x 0.4m opening) has been undermined/eroded. Well-defined sidewalls end.
	600m	1.5/45-35	40-50	8 @ 28 7 @ 55	4 @ 70	
	617m					Bedrock stream bed.
	650m	1.5/35	35-45	6 @ 25 14 @ 50	4.5 @ 50	
	650-673m					Bedrock stream bed.
	678m	80 us on rock				Inlet of 900mm CMP is 6m east along ditchline of CBR from natural channel.
	688m					C/L of Cypress Bowl Road GPS: 485381E/5467266N
	715m					Toe of rock fillslope.
	750m	2-3/30-40	33-40	10 @ 20	6.5 @ 50	Bedrock stream bed, continues to 850m. Locally steep stream gradient on rock slope.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	785m	/40-50				
	850m	1.5-2.5/45 us	40-50	8.5 @ 30	10 @ 45	Bedrock stream bed.
	873m					Crest of 100% bedrock lip. Flow is dispersed in multiple channels across 25m wide bedrock zone.
	934m	2-2.5/40-33	35-48	10 @ 60	16 @ 55	Flow is well-confined downstream from here.
	1032m	2/32	30	14 @ 30	17 @ 33	Bike trail at 1040m. Bedrock stream bed.
	1150m	2/45-25	40	15 @ 60	10.5 @ 58	Bedrock ledges prominent.
	1180m					Stream gradient @ 25-30% on bedrock joint.
	1250m	2/20-32	7-26	4 @ 35	6 @ 40	Mainly bedrock bed.
	1300m					Mainly bedrock bed with 0.5-1.0m high cutbanks in colluvium; multiple shallow channels locally.
	1350m	2/40-35	20-30	15 @ 30	5 @ 55	Small debris jams locally.
	1365m					Crest of bedrock cliff above Cypress Bowl Road.
	1370m					Inlet of 600mm CMP at Cypress Bowl Road. NB This culvert is smaller than 900mm CMP upstream.
	1380m					C/L of Cypress Bowl Road GPS: 485514E/5466706N Bedrock continuous along Cypress Bowl Road cut.
	1418m					Toe of rock fillslope.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	1450m	/30-48	40	9 @ 38	12 @ 25	Multiple shallow channels on bedrock over 12m width. Bedrock ledges continue downstream.
	1550m	/45-35	25-40	7 @ 55	8 @ 48	Multiple shallow channels on bedrock over 6m width.
	1588m					C/L of old road with ditchline that contributes to stream flow.
	1632m					Bedrock stream bed locally.
	1650m	/25	20-35	8.5 @ 36	15 @ 42	Two channels with 0.5-1m high cutbanks over 12m width. Till exposed in undermined bank.
	1700m			>20 @ 70	>20 @ 70	Long sidewalls likely developed in thicker till (ravine).
	1718m	2-2.5/35-25	23-32	20 @ 80	14 @ 60	
	1828m	2.5/22	22	11 @ 75	18 @ 42	Local 0.5m high cutbanks.
	1870m	35 ds				
	1885-1896m					Bedrock channel above inlet of 1200mm CMP at Cypress Bowl Road.
	1907m					C/L of Cypress Bowl Road GPS: 485449E/5466246N
	1980m					Outlet of 1800mm CMP under Deer Ridge Place. Left bank downstream of outlet is undermined; till bank 1m high.
	2000m	3/25	25	6 @ 35	2 @ 150 6 @ 60	Residence above left bank. Undermined banks have been shotcreted.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	2030m					Bedrock stream bed.
	2066m	3/37-25	40	6 @ 45	2.5 @ 100 4 @ 150	2-3m high cutbank in till on left bank. Large boulders in stream may deflect high flows onto banks. Bedrock stream bed.
	2080m	/30-15				
	2095m					Chain link fence
	2118m					Inlet of 1500mm CMP at Upper Levels Highway; has upstream trash rack. GPS: 485413E/5466050N POT
Tributary 1	0m					POC: south edge of pavement above 600mm CMP on Cypress Bowl Road. GPS: 485540E/5466700N
	35m					Toe of rock fillslope.
	150m	1.5-2/28	25-30	5 @ 30	3 @ 30	Bedrock stream bed. Thin colluvium (1m).
	180m	5/45 ds				Channel gradient and channel width increase on bedrock slope.
	226m	5/45-50	40-55	9 @ 65	6 @ 60	Bedrock stream bed.
	300m	1.5/15	20-25	7 @ 30	7.5 @ 30	
	390m	1.5/20	22-30	6 @ 20 6 @ 50	3.5 @ 30	Main channel dry, located on western edge of small fan that is 50m wide.
	455m					Till exposed in stream bed; dense to very dense with cobble to boulder clasts in sandy matrix.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	480m	2-3/28	28-35	6 @ 25	7 @ 60	Boulder lined channel.
	515m					Inlet of 900mm CMP under off-ramp from Upper Levels Highway. GPS: 485594E/5466265N POT
Tributary 2 (east of Tributary 1)	0m	0.5/25-35	25-30	6 @ 30	10 @ 20	POC: Upslope of Cypress Bowl Road at approximate headwaters of tributary. Ephemeral flow.
	87m	1/45-40	45	9 @ 40	6 @ 60	Cobble-boulder lined channel
	138m					C/L of Cypress Bowl Road. 800mm CMP conveys flow. GPS: 485700E/5466805N
	177m					Toe of rock fillslope.
	195m					Old berm from logging (?) has diverted stream and resulted in local bank erosion up to 1m high.
	225m	1-3/35	30-40	3 @ 40	6 @ 36	
	239m	/40-60	40-60			Steep bedrock-controlled gradient.
	279m	/58-37				Poor channel confinement on bedrock.
	325m	2/30-20	27-35	4 @ 25	8 @ 32	2 channels over 5m floodplain width.
	375m					Small tributary enters on left.
	422m	1.5-2/30-8	18-25	4 @ 20	5 @ 50	Boulder lined channel, no bedrock.
	503m	1.5/25-20	25	5 @ 35	6 @ 30	Sand-boulder substrate.

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
	535m					Creek has been diverted west along Cypress Lane ditchline. GPS: 485743E/5466400N POT
Downstream from Upper Levels Highway on Pipe Creek Mainstem						
3075 Spencer Court	Stream flows along east side of this property and is conveyed under Upper Levels Highway via 1500 mm metal pipe culvert with concrete outfall. Within the property, the left bank of the stream is retained by a concrete-rock wall that has locally been undermined by the stream.					
3072 Spencer Court	Downstream side of Spencer Court. The stream takes a sharp bend to the west and flows along the upslope (north) side of this property. The stream bed is bedrock but the concrete footing for a rock stack wall that supports the stream banks is being undermined and is locally collapsing.					
3094 Spencer Drive	The stream has been totally incorporated into the property landscaping with pools and block retaining walls constructed. No apparent erosion concerns.					
3090 Spencer Drive	Stream flows on bedrock through this property with no erosion concerns.					
3088 Spencer Place	Stream flows on bedrock through this property with no erosion concerns.					
3074 Spencer Place	Stream flows through 1800mm concrete pipe culvert then along east side of property. Retaining wall footings along right (west) bank are being undermined by stream flow. Property on east side of stream is being developed with soil disturbance extending to the stream channel; no erosion and sediment control measures in place. Stream flows through bedrock notch at rear of property.					
3040 Roseberry Avenue	Upstream of Roseberry Avenue, the stream channel is being modified as part of landscaping for new property development. Near Roseberry Avenue, there is local undermining of the till cutbank. Stream is conveyed under Roseberry Avenue via 1200mm concrete culvert then flows along east side of 3040 Roseberry Avenue. Pipe Creek Tributary 1 appears to have been diverted westward along ditchline of Roseberry Avenue and joins with mainstem near north end of this property. The stream through most of 3040 Roseberry Avenue is contained within a wide (5m) natural boulder-lined channel with no erosion concerns.					

STREAM	STATION	CHANNEL Width m/gradient % (upstream-downstream)	NATIVE SLOPE %	RB SLOPE (m @ % slope)	LB SLOPE (m @ % slope)	COMMENTS:
3033/3042 Mathers Avenue		Stream flows along west sides of these properties. The channel banks have been armoured with large rock or retained with concrete wall with only local minor undermining evident. Weir structures have also been installed to create riffle-pool sequence. The stream is conveyed under Mathers Avenue via a perched 1000mm pipe culvert with a 1m deep pool scoured at the outlet.				
3033 Marine Drive		Stream flows within natural channel along west side of this property. Small debris jams and minor bank erosion evident. Channel is 2.5m wide with gentle sideslopes. Bedrock underlies stream and forms banks along south half of property.				
3074 Marine Drive		Stream is conveyed under new portion of house within a 2m wide x 2.5m deep concrete channel. No erosion concerns.				
3094 Proctor Avenue		Stream flows under train tracks then along constructed concrete-rock channel (1m wide x 2m deep) within this property. No erosion concerns.				
160 31st St/124 31st St		Concrete channel continues through these properties before discharging to ocean. Channel is about 2m wide x 2m deep here. No erosion concerns.				
		POT				

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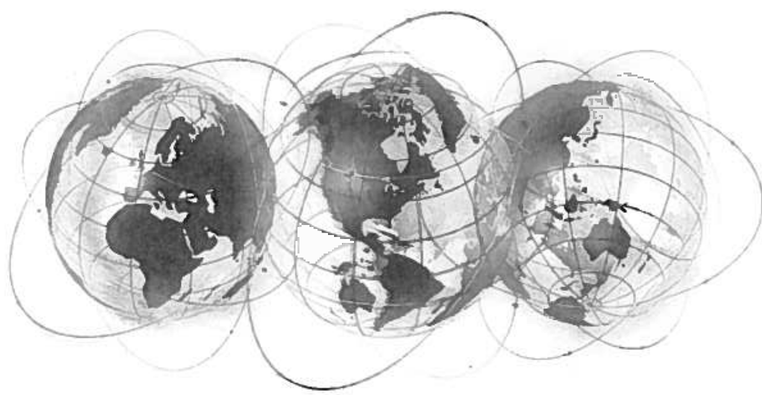

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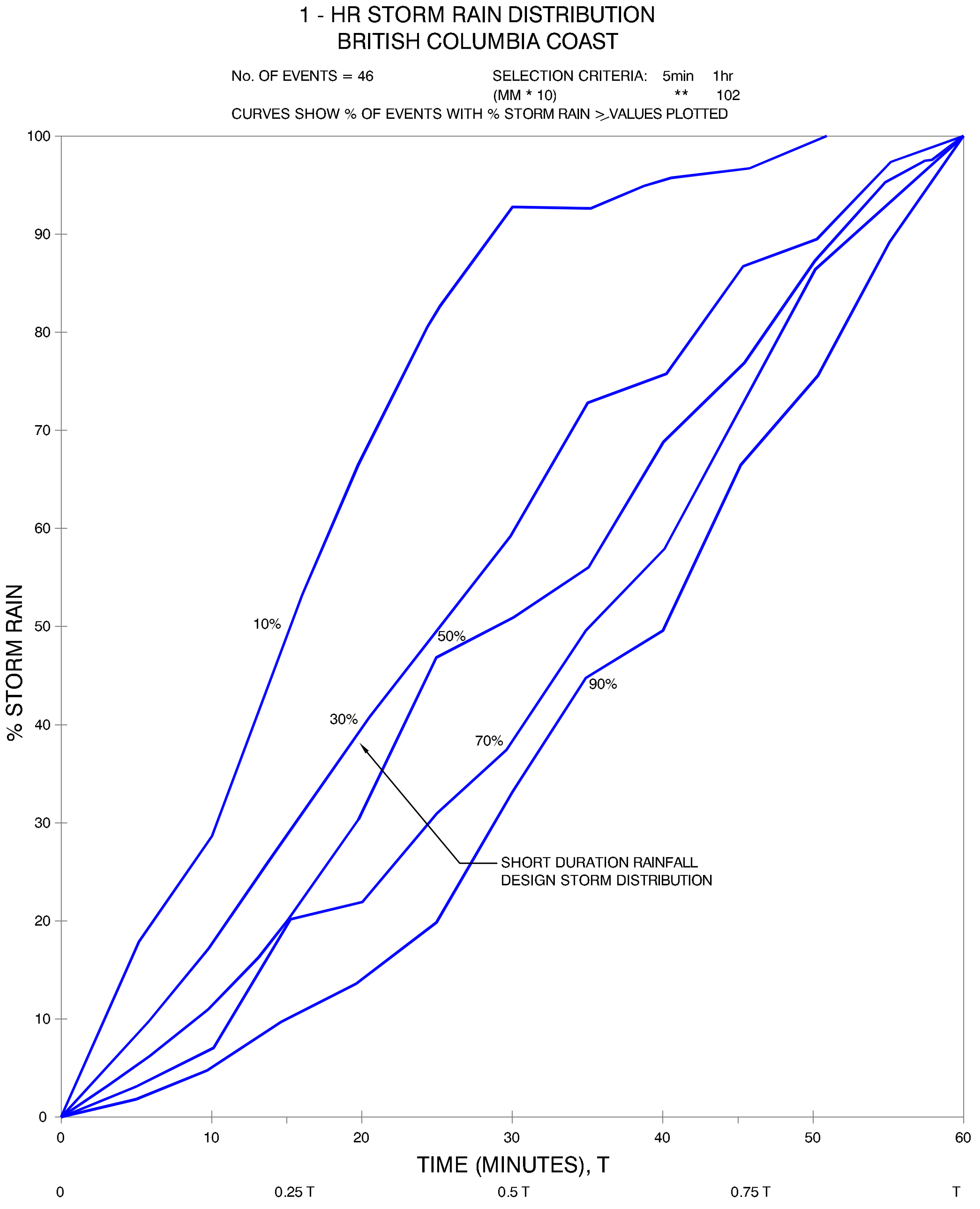
DISTRICT OF WEST VANCOUVER
INTEGRATED STORMWATER MANAGEMENT PLAN FOR PIPE, WESTMOUNT, CAVE, TURNER AND GODMAN CREEKS

APPENDIX D

AES STORM DISTRIBUTION GRAPHS AND INTENSITY DURATION FREQUENCY CURVE FOR WEST VANCOUVER MUNICIPAL STATION (VW14)



1 HOUR STORM DISTRIBUTION

(FOR HYETOGRAPH DEVELOPMENT)

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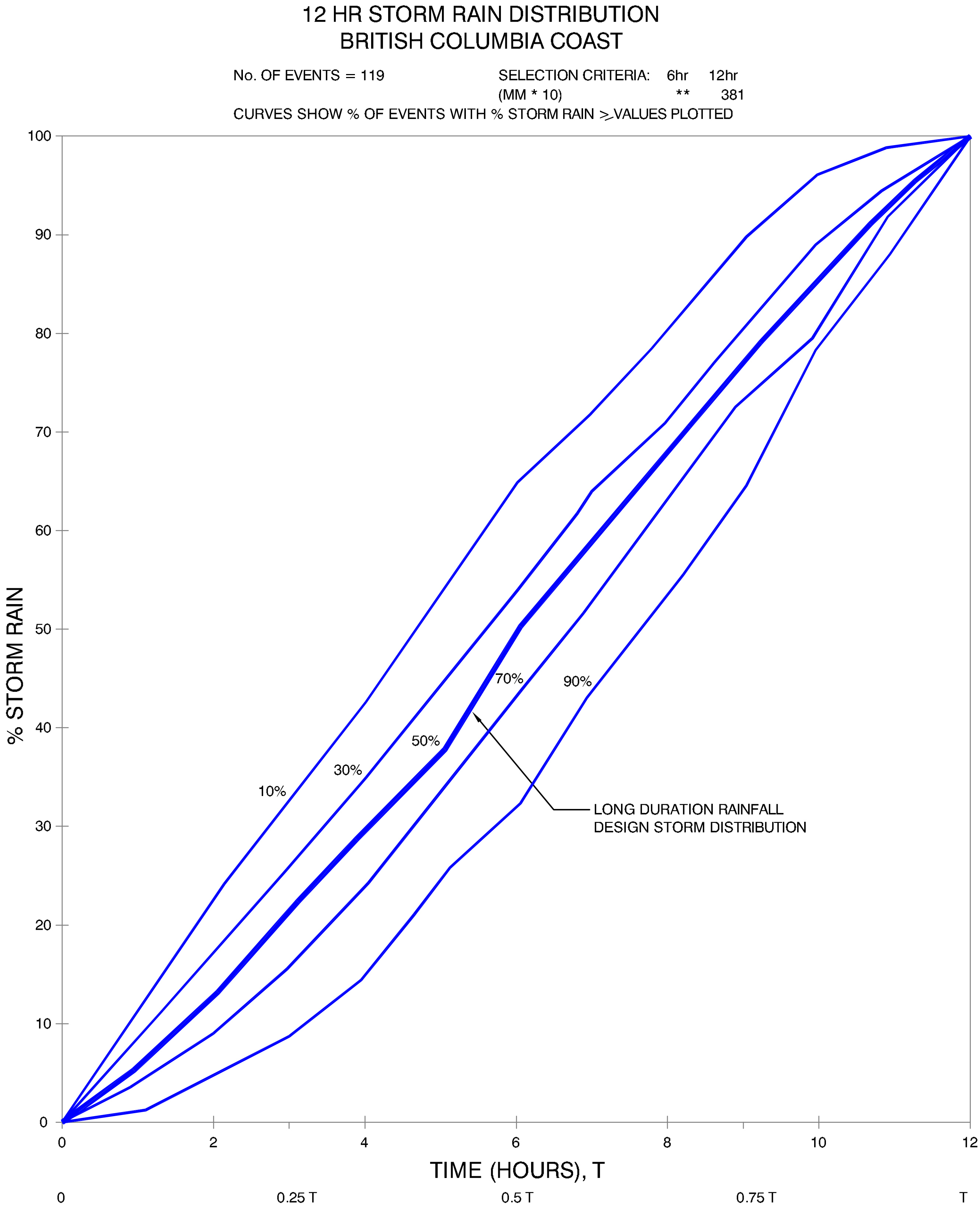
APPENDIX C-1



12 HOUR STORM DISTRIBUTION

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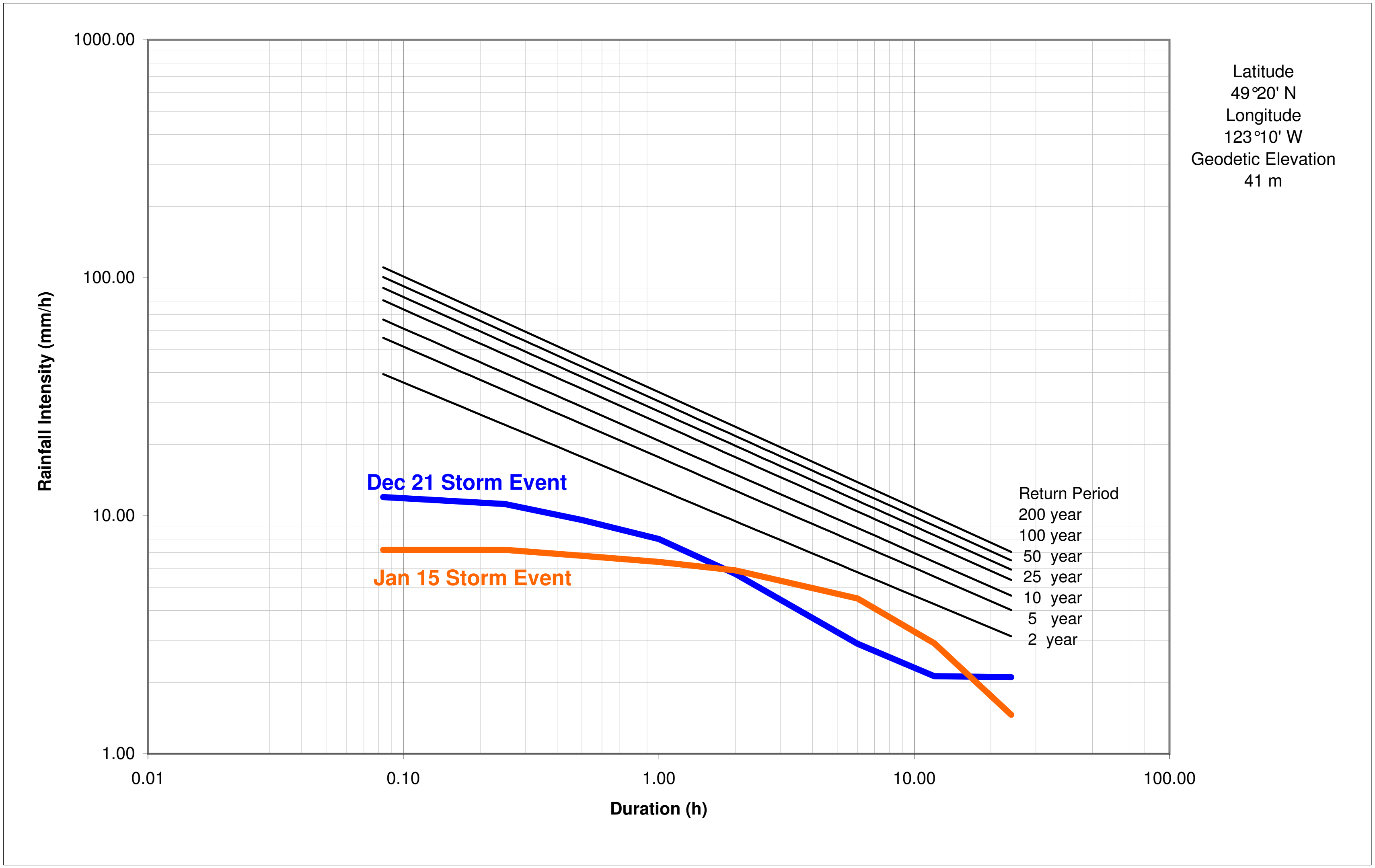
APPENDIX C-2

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT
RAINFALL INTENSITY-DURATION FREQUENCY DATA (SHORT DURATION) FOR
WEST VANCOUVER MUNICIPAL HALL (STATION VW14)
BASED ON RECORDING RAIN GAUGE DATA FOR THE PERIOD 1959 - 1979 AND 1983 - 2005 (44 YEARS)



File: RainVW14IDF-Graph
Sheet: IDF Graph (Short)

8/18/2010

DISTRICT OF WEST VANCOUVER
INTEGRATED STORMWATER MANAGEMENT PLAN FOR PIPE, WESTMOUNT, CAVE, TURNER AND GODMAN CREEKS

APPENDIX E

DESIGN STORMS AND HYETOGRAPHS

TABLE E-1
1 HOUR DESIGN STORM

Time (min)	1 Hour Design Storm (Volume of Rainfall in Interval (mm)			
	1:2 year storm	1:10 year storm	1:100 year storm	1:200 year storm
0	0.00	0.00	0.00	0.00
5	1.06	1.70	2.48	2.72
10	1.26	2.01	2.94	3.21
15	1.41	2.26	3.30	3.61
20	1.45	2.32	3.39	3.71
25	1.30	2.07	3.03	3.31
30	1.30	2.07	3.03	3.31
35	1.67	2.67	3.91	4.27
40	0.39	0.62	0.91	0.99
45	1.31	2.09	3.06	3.35
50	0.44	0.70	1.03	1.13
55	1.00	1.59	2.33	2.55
60	0.38	0.60	0.88	0.96
Total Rainfall	12.96	20.71	30.29	33.12

TABLE E-2
2 HOUR DESIGN STORM

Time (min)	2 Hour Design Storm (Volume of Rainfall in Interval (mm)			
	1:2 year storm	1:10 year storm	1:100 year storm	1:200 year storm
0	0.00	0.00	0.00	0.00
10	1.56	2.45	3.55	3.88
20	1.84	2.90	4.20	4.59
30	2.07	3.25	4.72	5.15
40	2.13	3.34	4.85	5.30
50	1.90	2.99	4.33	4.73
60	1.90	2.99	4.33	4.73
70	2.45	3.85	5.59	6.10
80	0.57	0.90	1.30	1.42
90	1.92	3.02	4.38	4.78
100	0.65	1.02	1.47	1.61
110	1.46	2.30	3.34	3.64
120	0.55	0.87	1.26	1.37
Total Rainfall	19.00	29.86	43.32	47.28

TABLE E-3
6 HOUR DESIGN STORM

Time (hr)	6 Hour Design Storm (Volume of Rainfall in Interval (mm)			
	1:2 year storm	1:10 year storm	1:100 year storm	1:200 year storm
0.00	0.00	0.00	0.00	0.00
0.25	0.98	1.48	2.11	2.30
0.50	0.98	1.48	2.11	2.30
0.75	1.21	1.83	2.61	2.84
1.00	1.21	1.83	2.61	2.84
1.25	1.42	2.16	3.08	3.35
1.50	1.42	2.16	3.08	3.35
1.75	1.36	2.06	2.93	3.19
2.00	1.36	2.06	2.93	3.19
2.25	1.26	1.91	2.72	2.96
2.50	1.26	1.91	2.72	2.96
2.75	2.05	3.11	4.43	4.82
3.00	2.05	3.11	4.43	4.82
3.25	1.36	2.06	2.93	3.19
3.50	1.36	2.06	2.93	3.19
3.75	1.60	2.44	3.47	3.77
4.00	1.60	2.44	3.47	3.77
4.25	1.52	2.31	3.29	3.58
4.50	1.52	2.31	3.29	3.58
4.75	1.45	2.21	3.15	3.42
5.00	1.45	2.21	3.15	3.42
5.25	1.26	1.91	2.72	2.96
5.50	1.26	1.91	2.72	2.96
5.75	1.07	1.63	2.32	2.53
6.00	1.07	1.63	2.32	2.53
Total Rainfall	33.06	50.22	71.52	77.82

TABLE E-4
12 HOUR DESIGN STORM

Time (hr)	12 Hour Design Storm (Volume of Rainfall in Interval (mm)			
	1:2 year storm	1:10 year storm	1:100 year storm	1:200 year storm
0.0	0.00	0.00	0.00	0.00
0.5	1.43	2.22	3.21	3.50
1.0	1.43	2.22	3.21	3.50
1.5	1.77	2.75	3.97	4.33
2.0	1.77	2.75	3.97	4.33
2.5	2.08	3.24	4.67	5.10
3.0	2.08	3.24	4.67	5.10
3.5	1.99	3.09	4.46	4.86
4.0	1.99	3.09	4.46	4.86
4.5	1.84	2.86	4.13	4.51
5.0	1.84	2.86	4.13	4.51
5.5	3.01	4.67	6.74	7.35

Time (hr)	12 Hour Design Storm (Volume of Rainfall in Interval (mm)			
	1:2 year storm	1:10 year storm	1:100 year storm	1:200 year storm
6.0	3.01	4.67	6.74	7.35
6.5	1.99	3.09	4.46	4.86
7.0	1.99	3.09	4.46	4.86
7.5	2.35	3.65	5.27	5.75
8.0	2.35	3.65	5.27	5.75
8.5	2.23	3.47	5.00	5.45
9.0	2.23	3.47	5.00	5.45
9.5	2.13	3.32	4.78	5.22
10.0	2.13	3.32	4.78	5.22
10.5	1.84	2.86	4.13	4.51
11.0	1.84	2.86	4.13	4.51
11.5	1.58	2.45	3.53	3.85
12.0	1.58	2.45	3.53	3.85
Total Rainfall	48.48	75.36	108.72	118.56

TABLE E-5
24 HOUR DESIGN STORM

Time (hr)	24 Hour Design Storm (Volume of Rainfall in Interval (mm)			
	1:2 year storm	1:10 year storm	1:100 year storm	1:200 year storm
0	0.00	0.00	0.00	0.00
1	2.10	3.33	4.87	5.32
2	2.10	3.33	4.87	5.32
3	2.59	4.13	6.03	6.59
4	2.59	4.13	6.03	6.59
5	3.05	4.86	7.10	7.76
6	3.05	4.86	7.10	7.76
7	2.91	4.63	6.77	7.40
8	2.91	4.63	6.77	7.40
9	2.70	4.30	6.27	6.86
10	2.70	4.30	6.27	6.86
11	4.40	7.01	10.24	11.19
12	4.40	7.01	10.24	11.19
13	2.91	4.63	6.77	7.40
14	2.91	4.63	6.77	7.40
15	3.45	5.48	8.01	8.75
16	3.45	5.48	8.01	8.75
17	3.27	5.20	7.60	8.30
18	3.27	5.20	7.60	8.30
19	3.13	4.97	7.27	7.94
20	3.13	4.97	7.27	7.94
21	2.70	4.30	6.27	6.86
22	2.70	4.30	6.27	6.86
23	2.31	3.67	5.37	5.87
24	2.31	3.67	5.37	5.87
Total Rainfall	71.04	113.04	165.12	180.48

Figure E-1: 2 Year 1 Hour Storm Hyetograph (Station VW14)

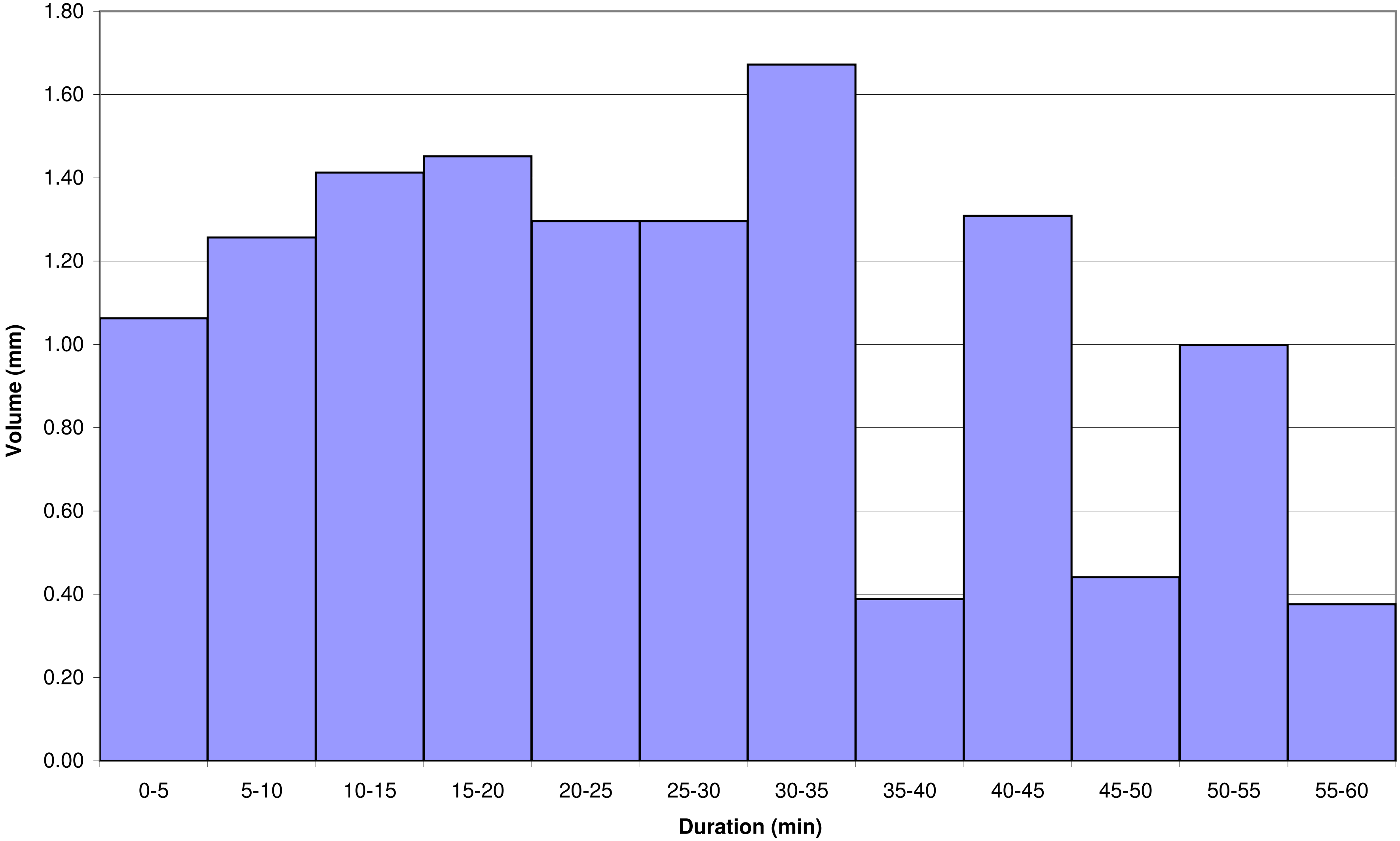


Figure E-2: 10 Year 1 Hour Storm Hyetograph (VW14)

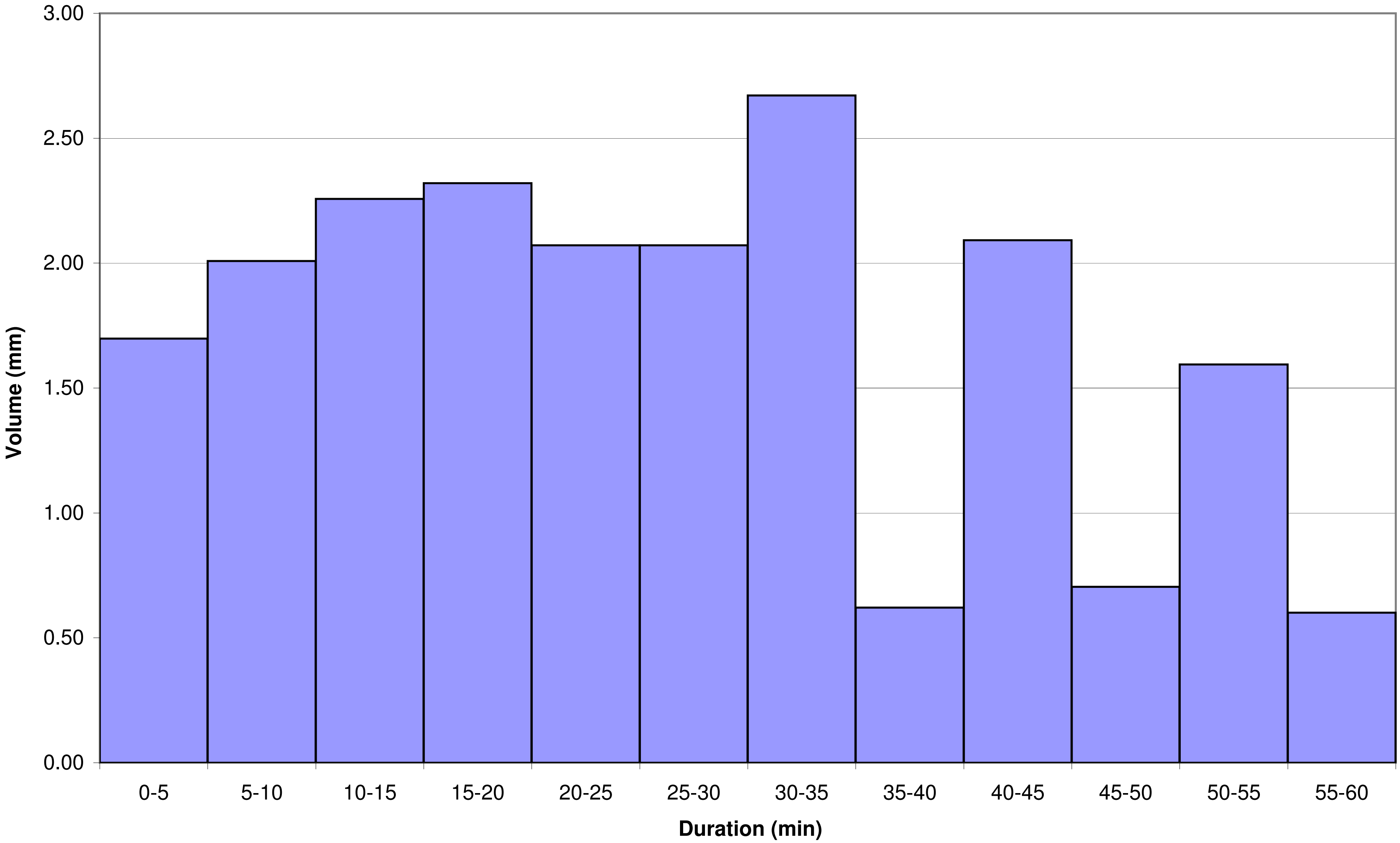


Figure E-3: 100 Year 1 Hour Storm Hyetograph (VW14)

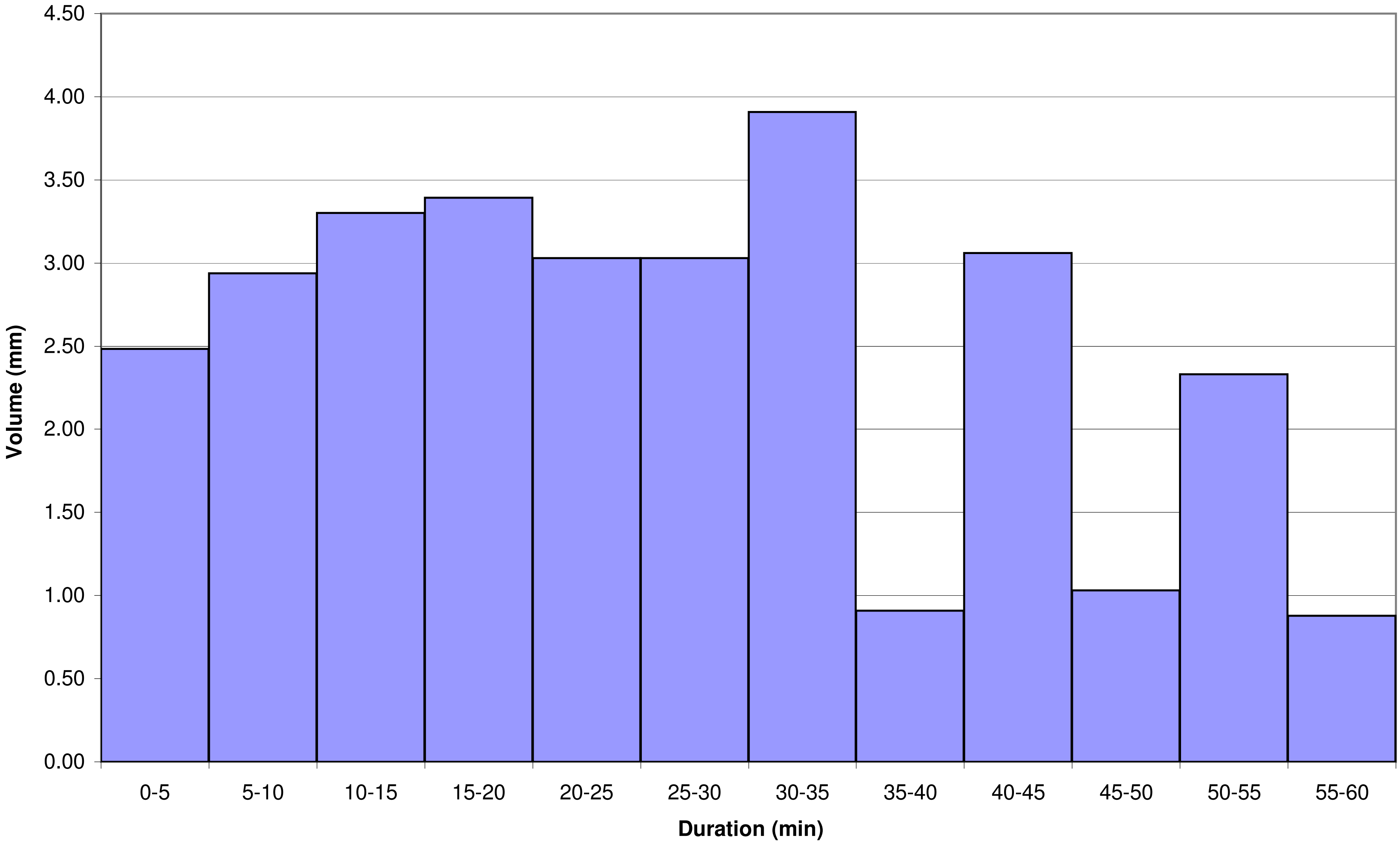


Figure E-4: 200 Year 1 Hour Storm Hyetograph (VW14)

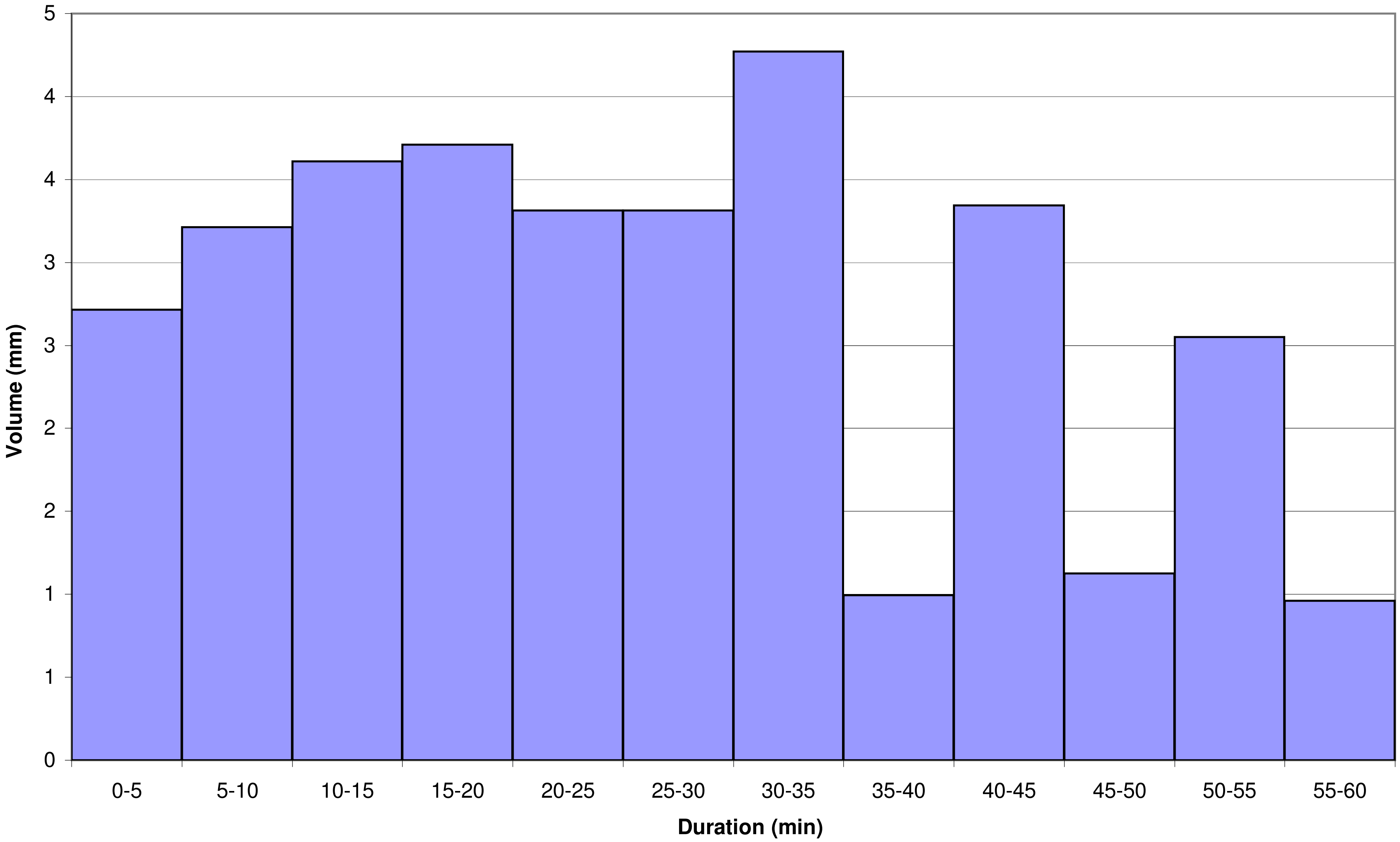


Figure E-5: 2 Year 2 Hour Storm Hyetograph (Station VW14)

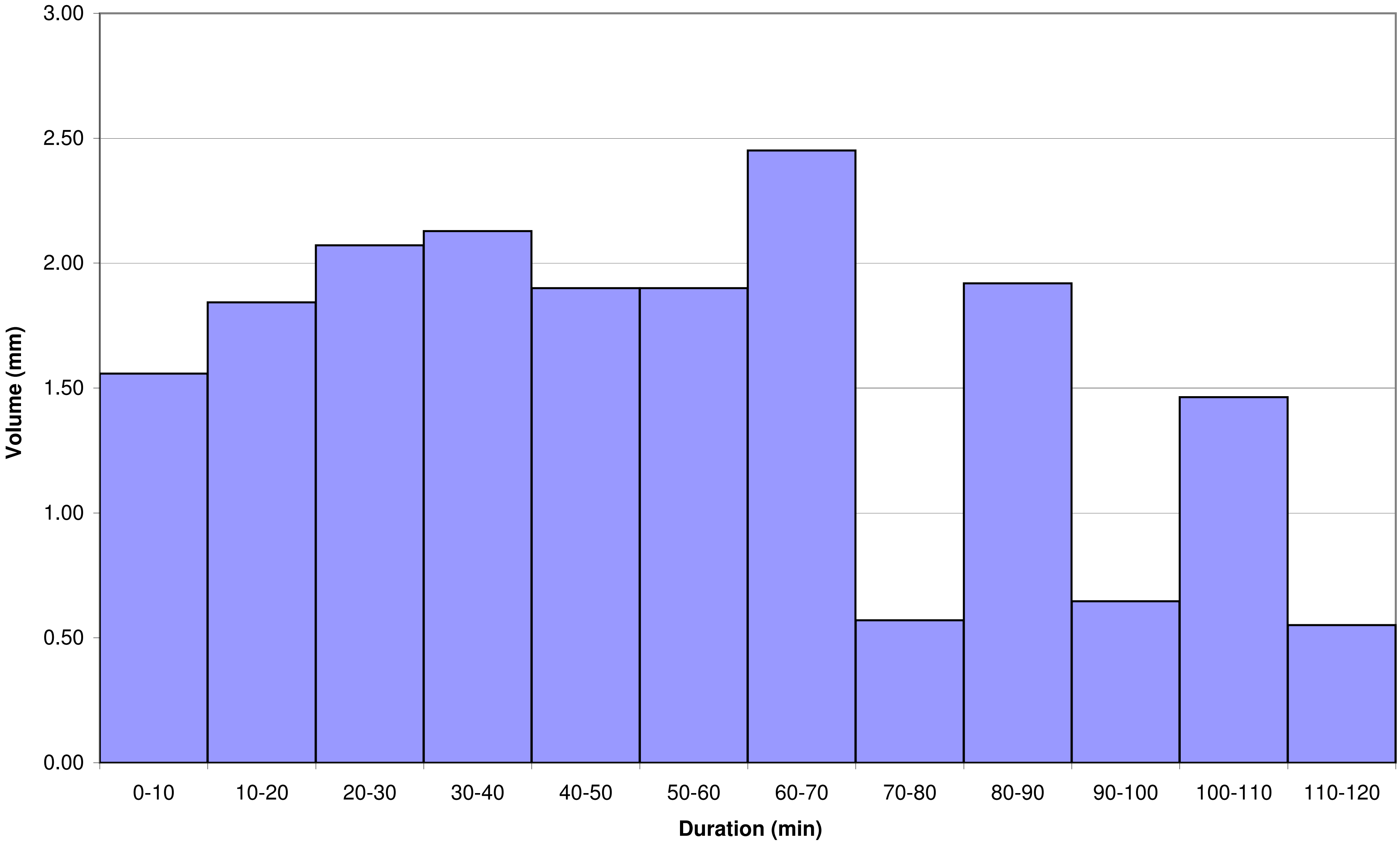


Figure E-6: 10 Year 2 Hour Storm Hyetograph (VW14)

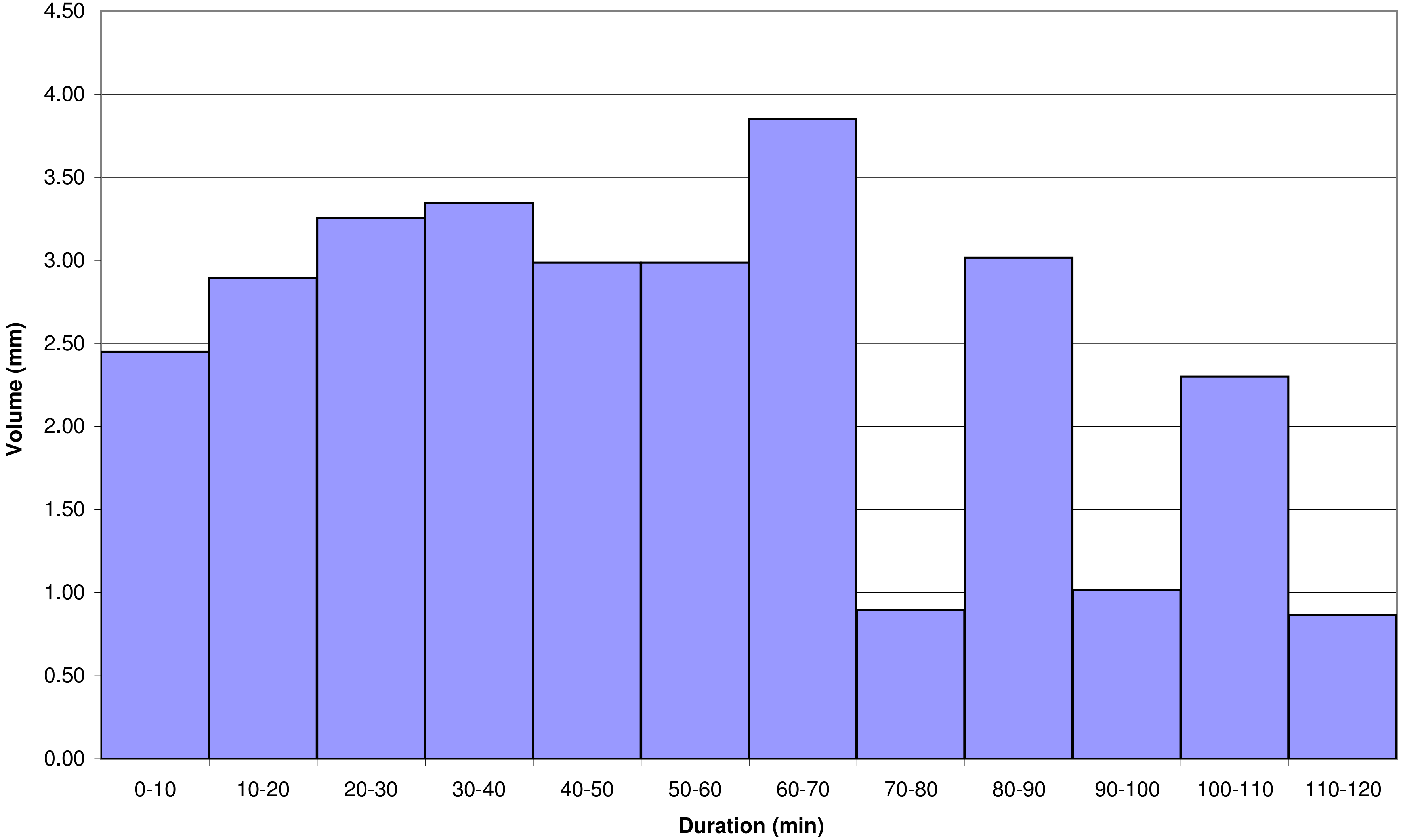


Figure E-7: 100 Year 2 Hour Storm Hyetograph (VW14)

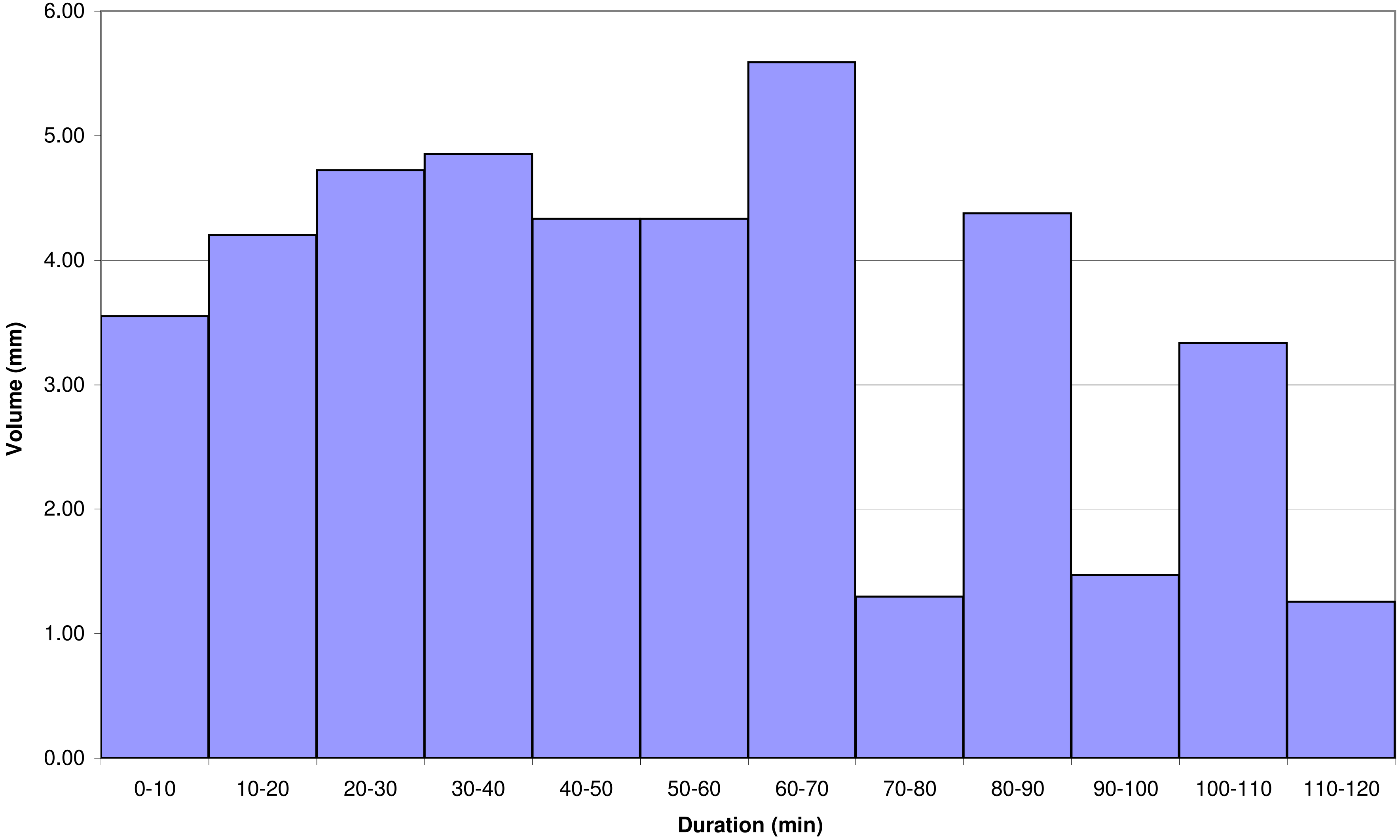


Figure E-8: 200 Year 2 Hour Storm Hyetograph (VW14)

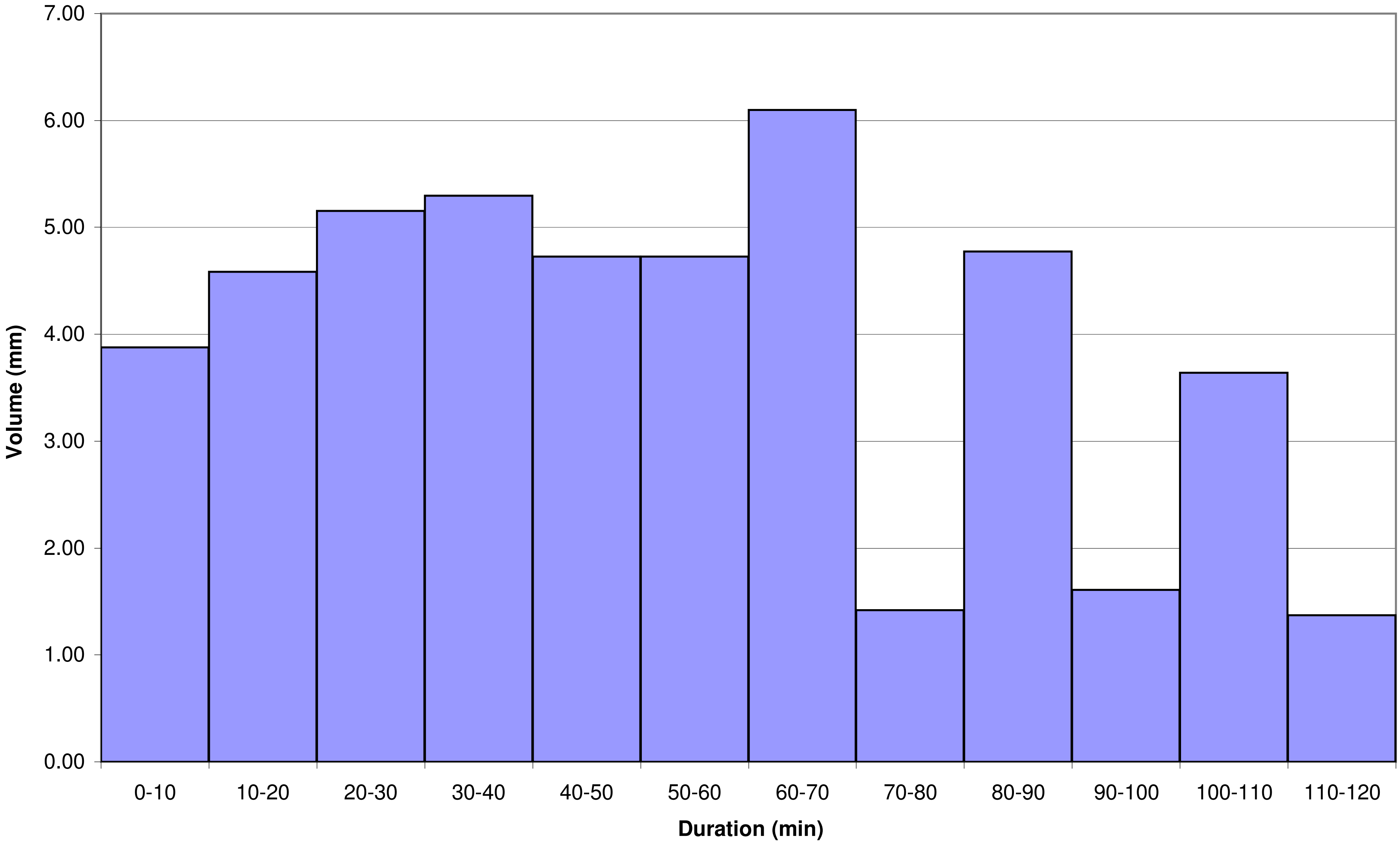


Figure E-9: 2 Year 6 Hour Storm Hyetograph (Station VW14)

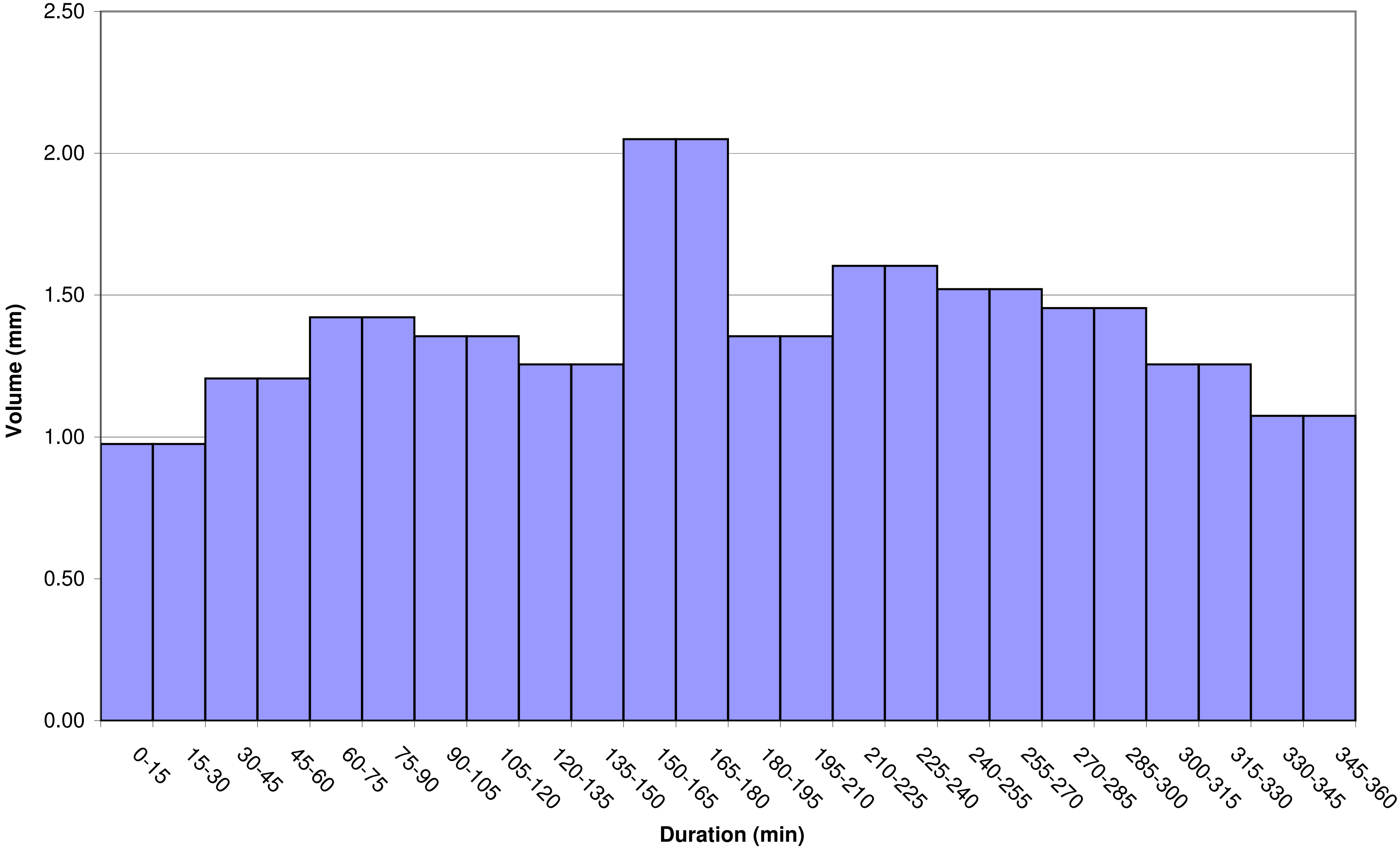


Figure E-10: 10 Year 6 Hour Storm Hyetograph (VW14)

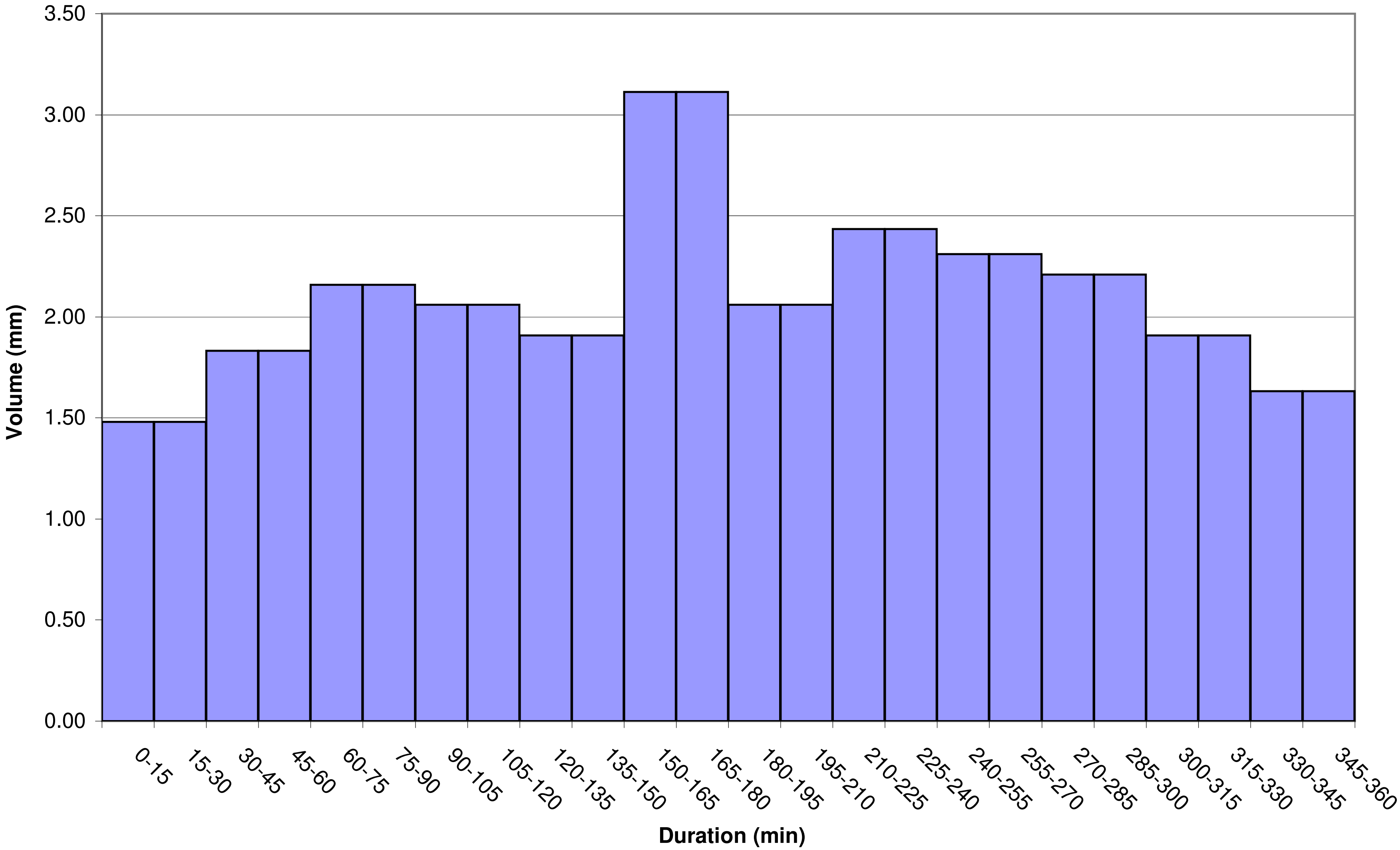


Figure E-11: 100 Year 6 Hour Storm Hyetograph (VW14)

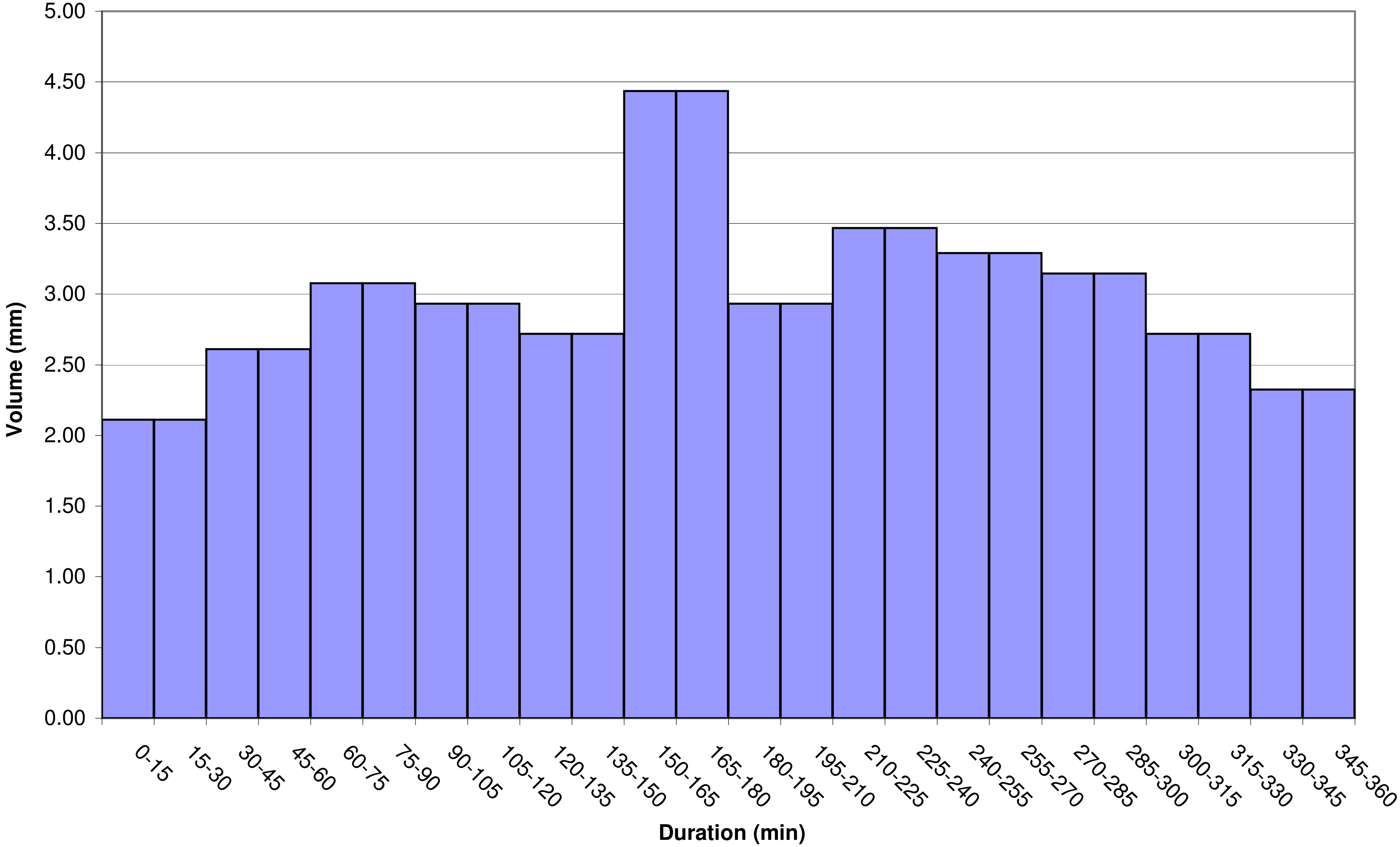


Figure E-12: 200 Year 6 Hour Storm Hyetograph (VW14)

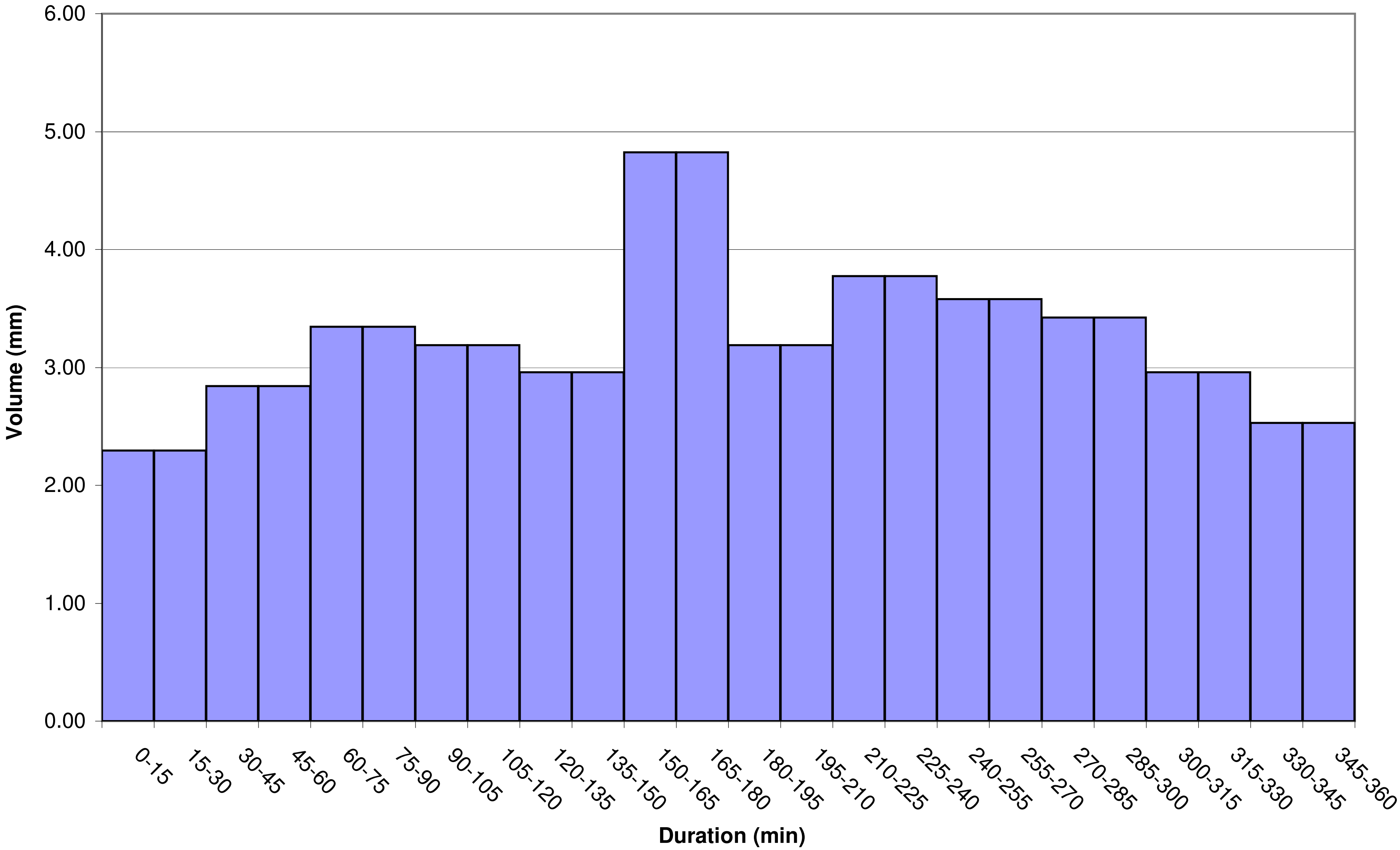


Figure E-13: 2 Year 12 Hour Storm Hyetograph (Station VW14)

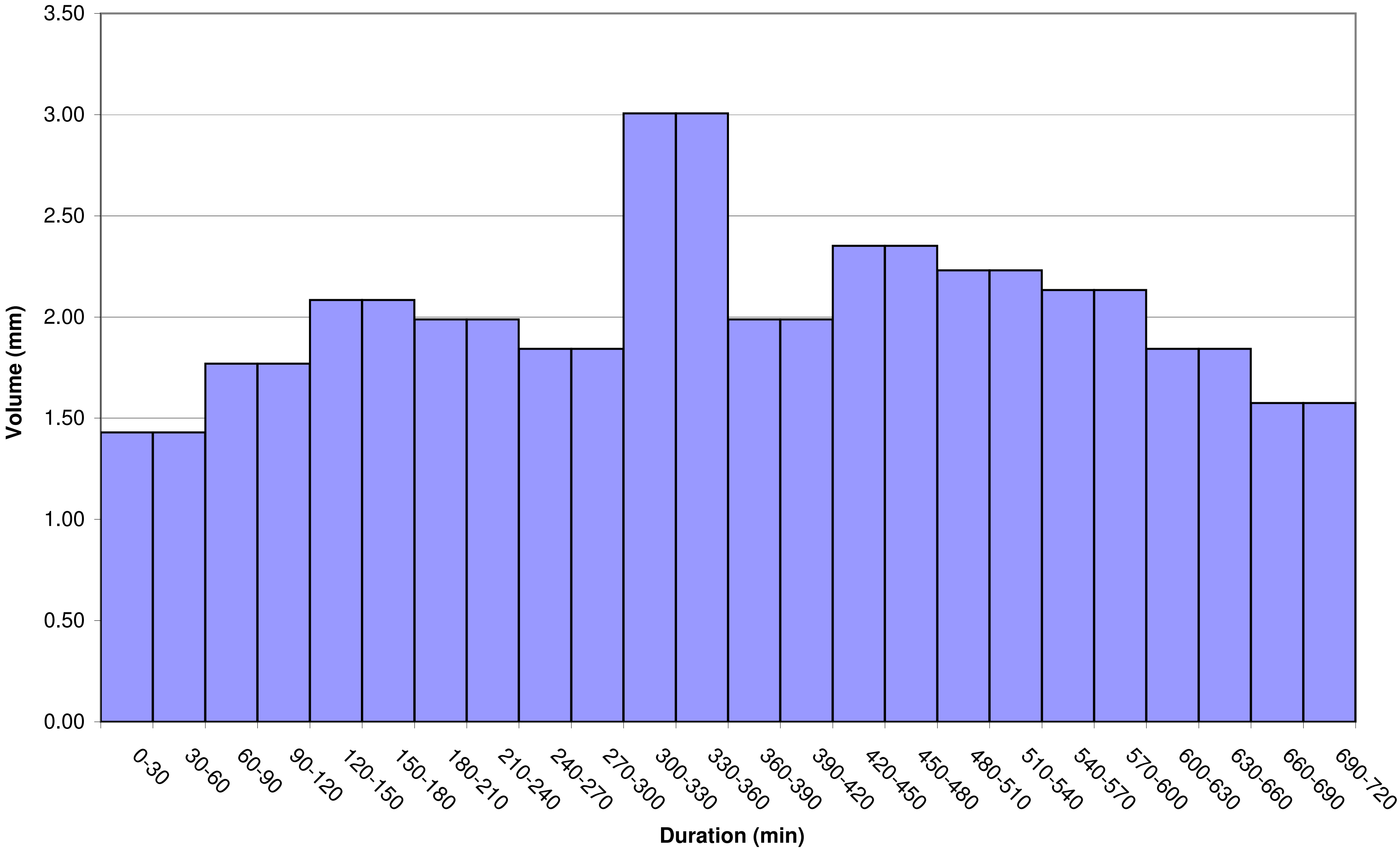


Figure E-14: 10 Year 12 Hour Storm Hyetograph (VW14)

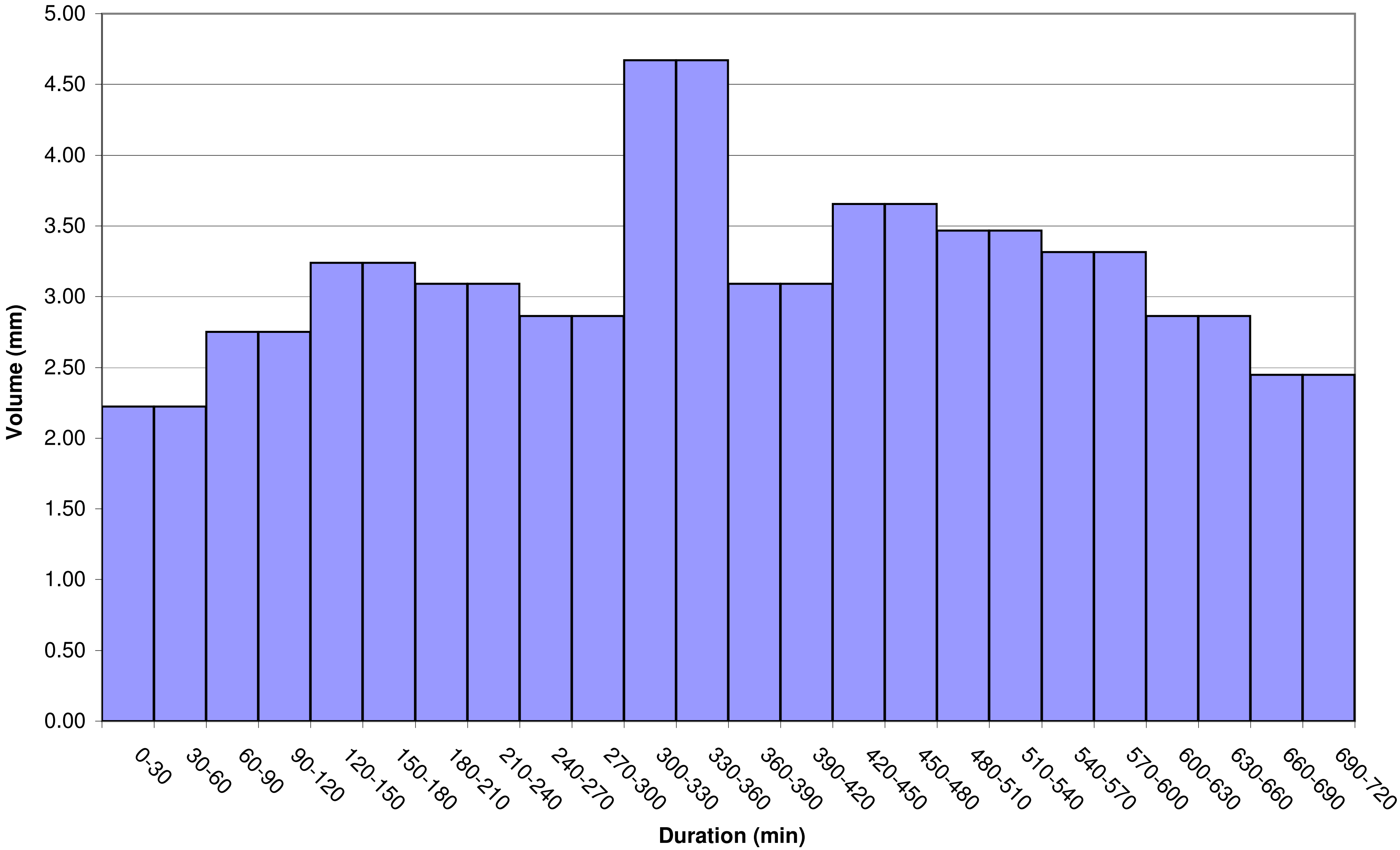


Figure E-15: 100 Year 12 Hour Storm Hyetograph (VW14)

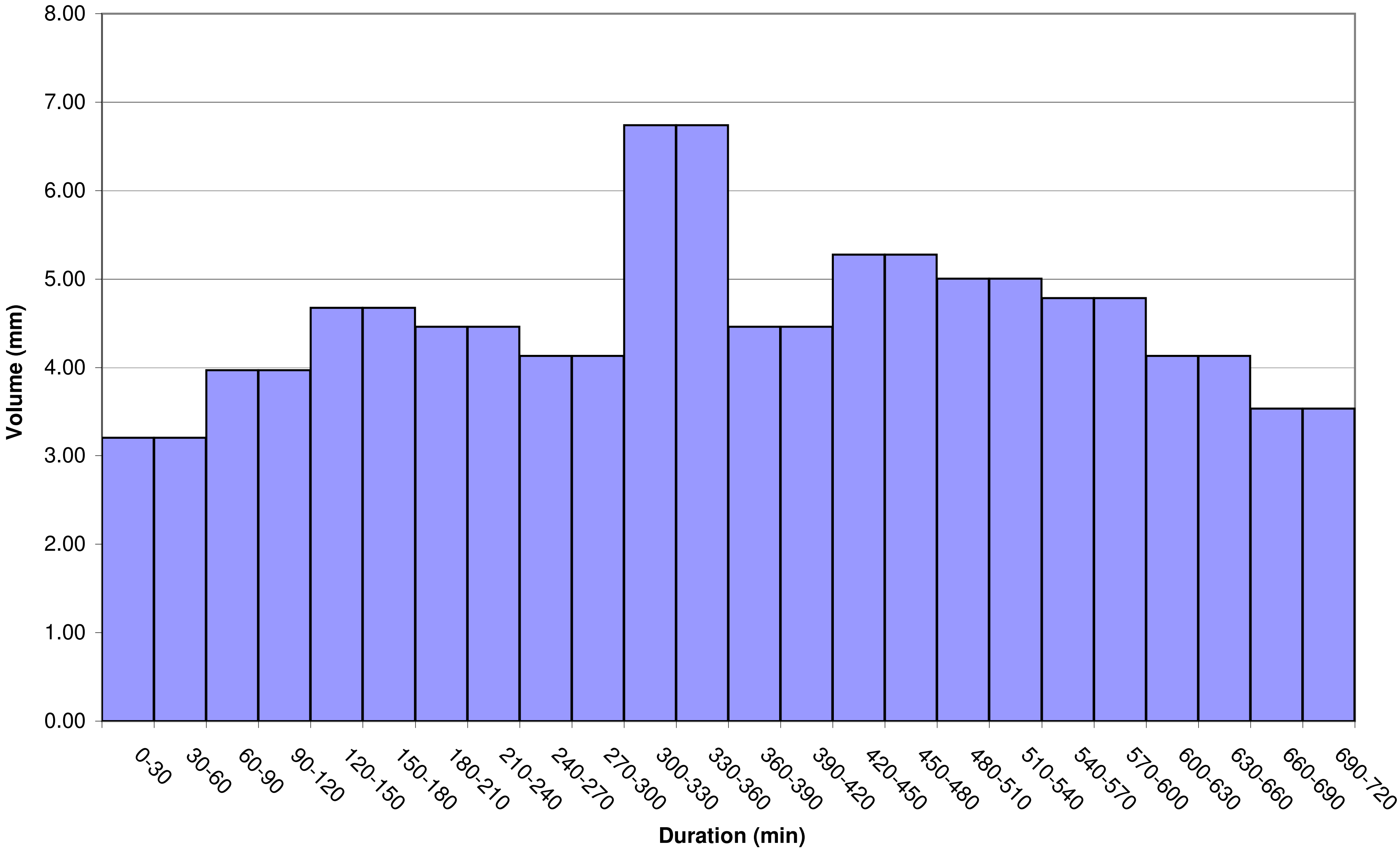


Figure E-16: 200 Year 12 Hour Storm Hyetograph (VW14)

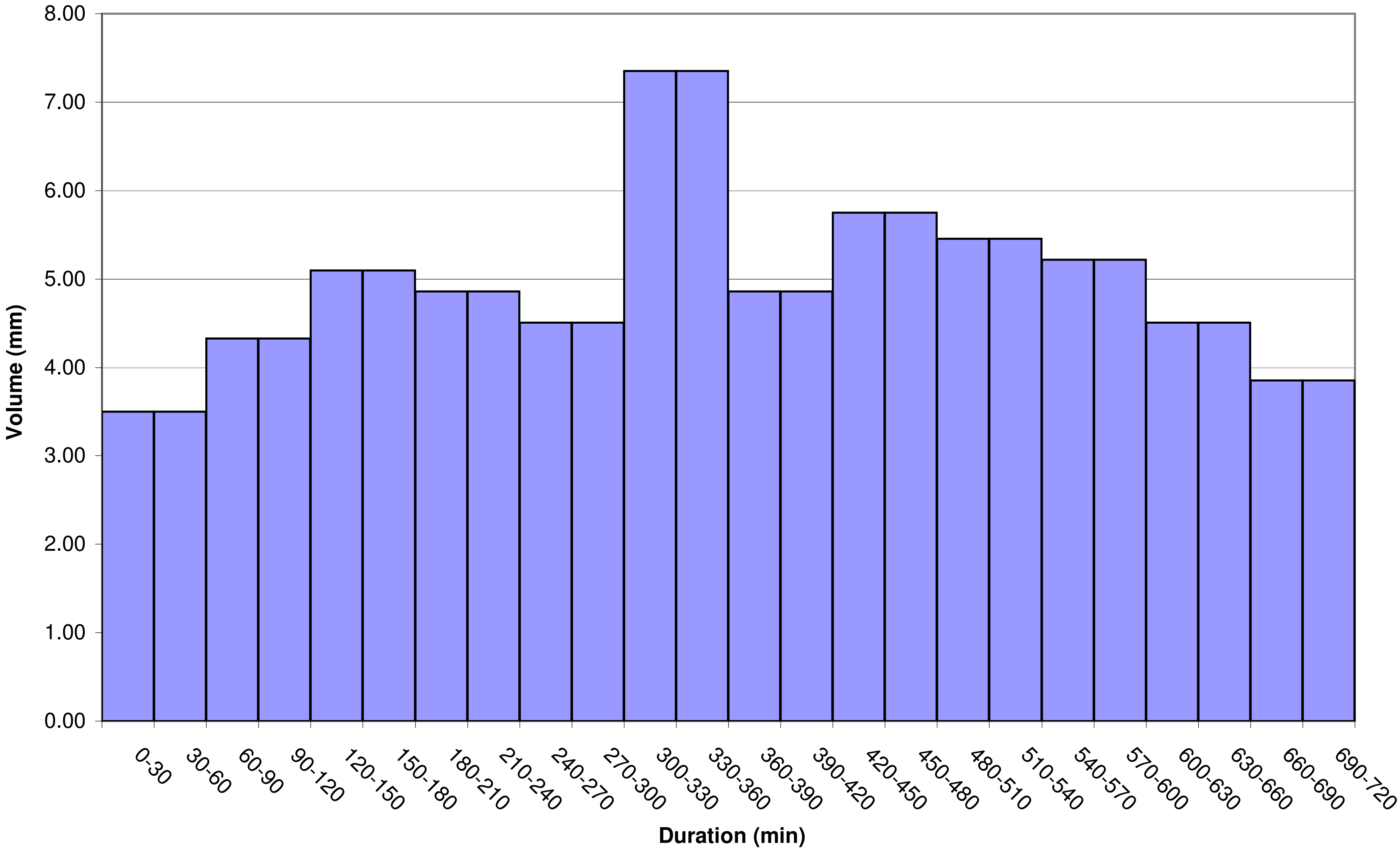


Figure E-17: 2 Year 24 Hour Storm Hyetograph (Station VW14)

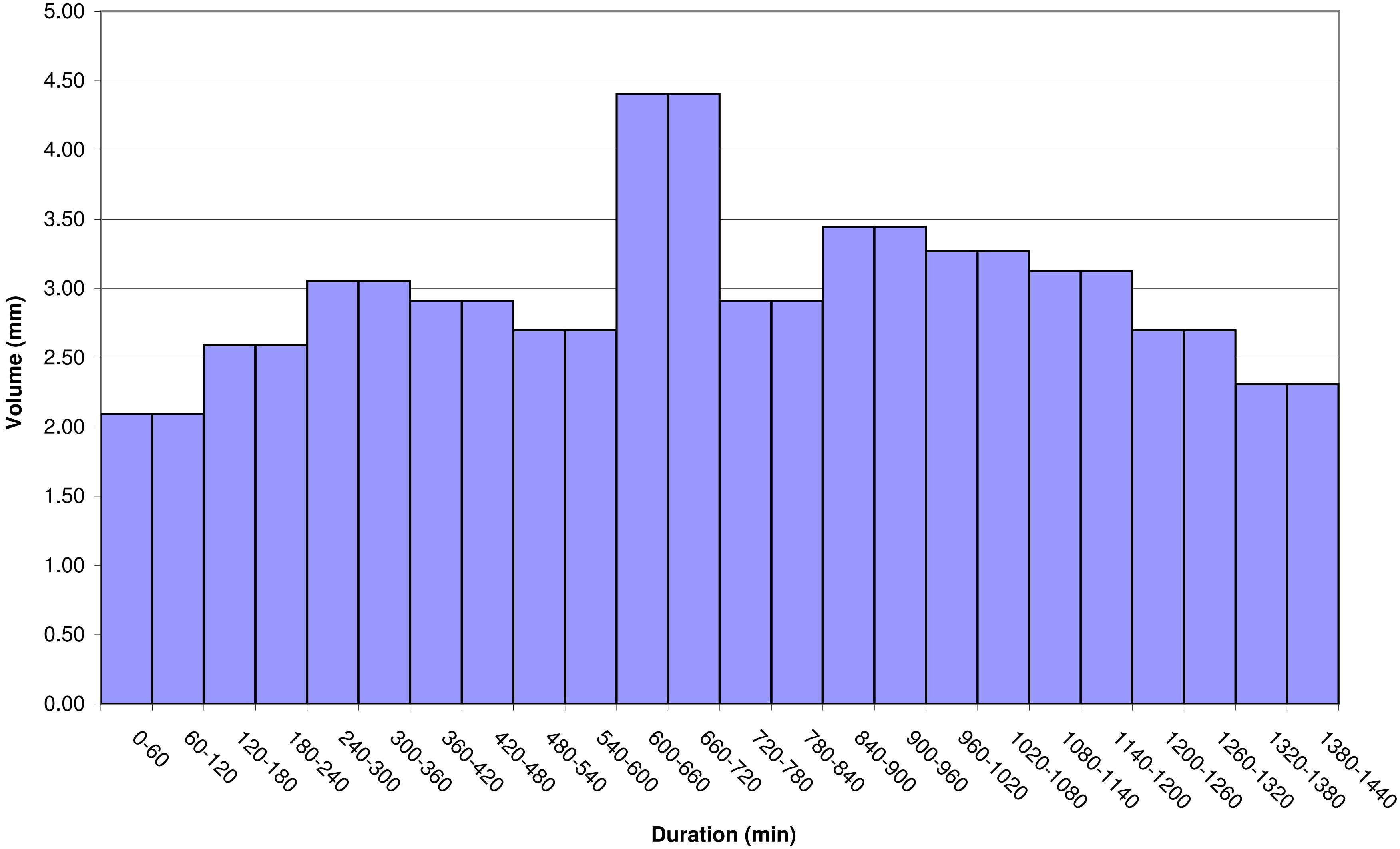


Figure E-18: 10 Year 24 Hour Storm Hyetograph (VW14)

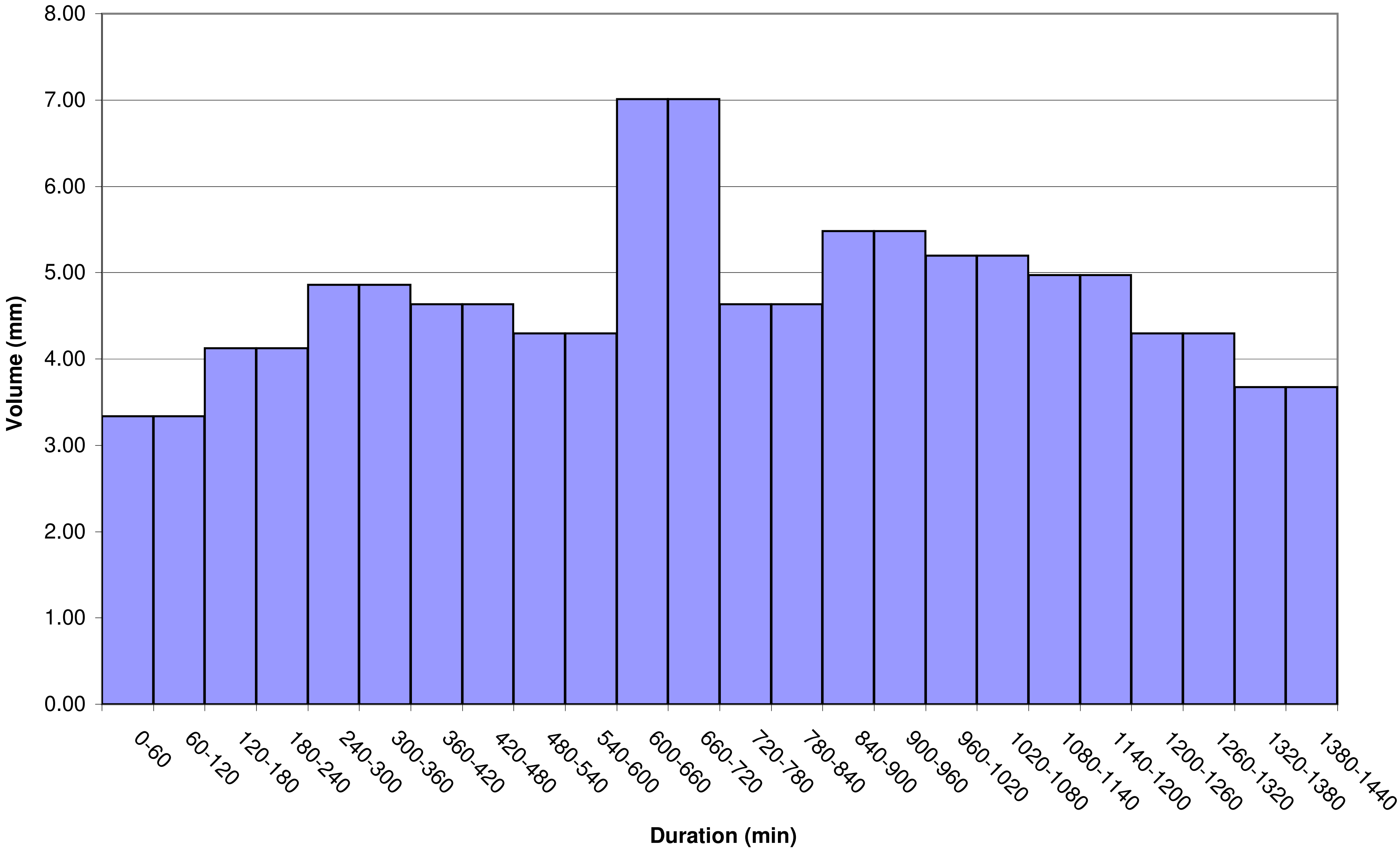
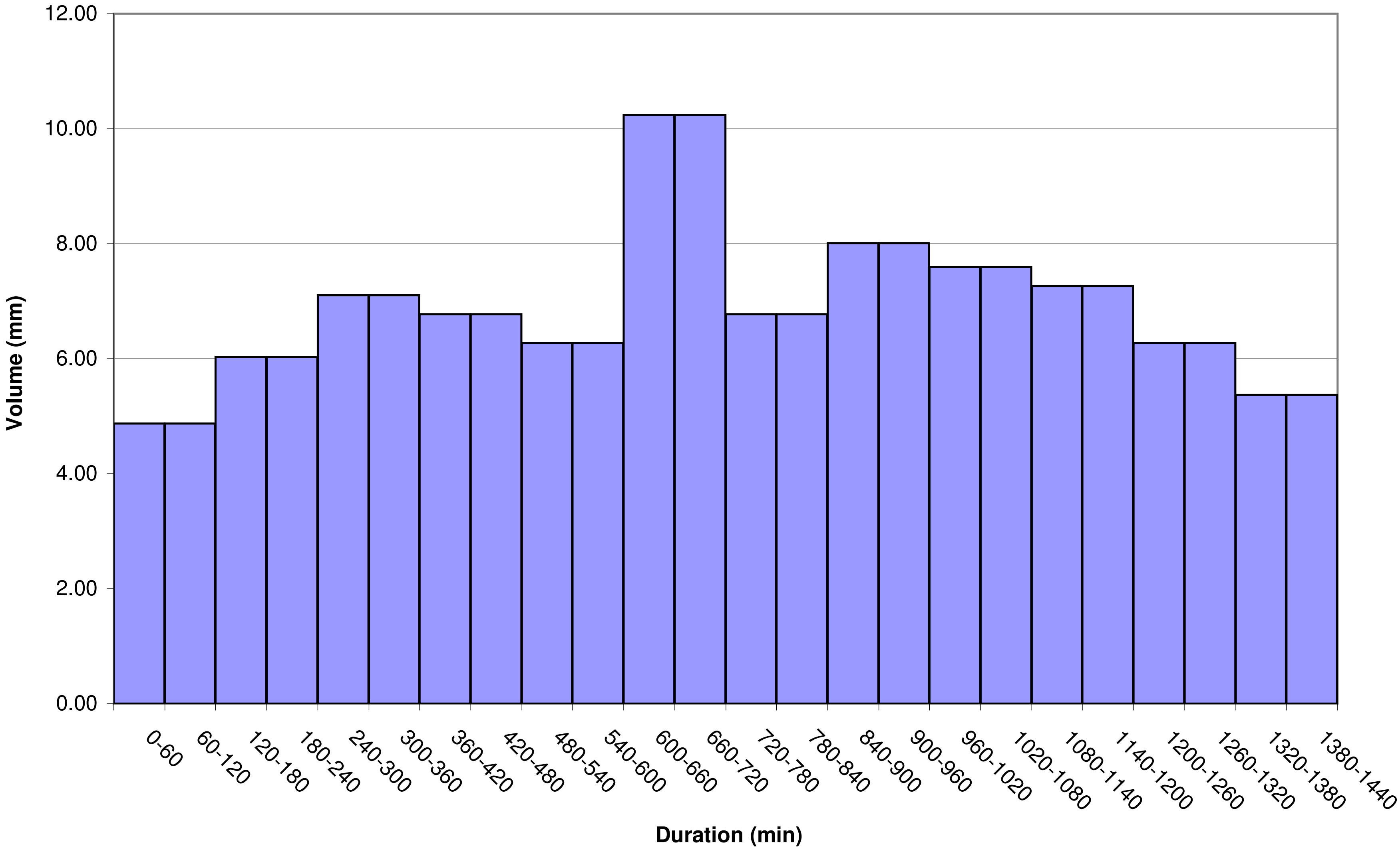


Figure E-19: 100 Year 24 Hour Storm Hyetograph (VW14)



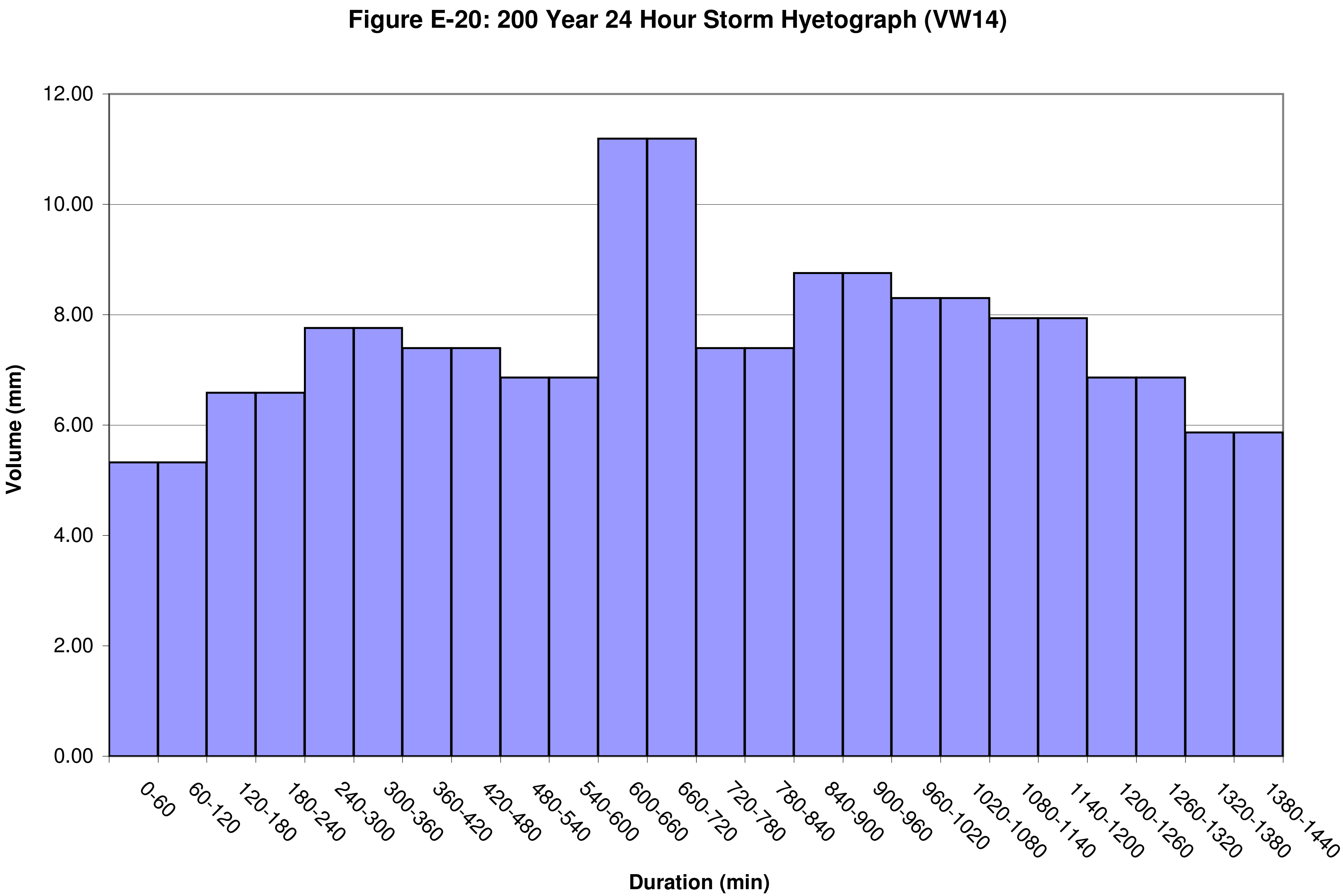


Figure E-20: 200 Year 24 Hour Storm Hyetograph (VW14)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Volume (mm)
0-60
60-120
120-180
180-240
240-300
300-360
360-420
420-480
480-540
540-600
600-660
660-720
720-780
780-840
840-900
900-960
960-1020
1020-1080
1080-1140
1140-1200
1200-1260
1260-1320
1320-1380
1380-1440
Duration (min)

DISTRICT OF WEST VANCOUVER
INTEGRATED STORMWATER MANAGEMENT PLAN FOR PIPE, WESTMOUNT, CAVE, TURNER AND GODMAN CREEKS

APPENDIX F

IMPERVIOUSNESS PRE- AND POST-DEVELOPMENT

TABLE F-1
GODMAN CREEK SUBCATCHMENTS
IMPERVIOUS PERCENTAGES

Area ID	Area ha	Pre-Development Impervious %	Post-Development Impervious %
1-1	0.53	59	59
1-2	0.63	42	42
1-3	2.15	17	17
1-4	15.17	37	37
1-5	10.71	34	34
1-6	2.53	35	35
1-7	13.28	22	22
1-8	24.44	3	27
1-9	53.43	4	20
1-10	30.68	0	0
1-11	28.68	2	2

TABLE F-2
TURNER CREEK SUBCATCHMENTS
IMPERVIOUS PERCENTAGES

Area ID	Area ha	Pre-Development Impervious %	Post-Development Impervious %
2-1	0.70	38	38
2-2	4.25	37	37
2-3	2.19	23	23
2-4	1.07	38	38
2-5	2.17	30	30
2-6	5.41	31	31
2-7	4.29	36	36
2-8	1.10	20	20
2-9	2.67	59	59
2-10	1.35	42	42
2-11	2.81	54	54
2-12	1.58	9	9
2-13	6.28	2	2
2-14	5.62	11	11
2-15	13.44	21	21
2-16	11.47	0	0

TABLE F-3
CAVE CREEK SUBCATCHMENTS
IMPERVIOUS PERCENTAGES

Area ID	Area ha	Pre-Development Impervious %	Post-Development Impervious %
3-1	0.04	30	30
3-2	0.55	0	0
3-3	0.05	35	35
3-4	0.83	36	36
3-5	20.12	34	34
3-6	12.13	8	8
3-7	1.19	9	9
3-8	2.10	7	8
3-9	5.51	0	7
3-10	20.79	1	1
3-11	1.29	8	14
3-12	4.90	0	13
3-13	1.10	13	21
3-14	8.71	1	13
3-15	8.66	3	3

TABLE F-4
WESTMOUNT CREEK SUBCATCHMENTS
IMPERVIOUS PERCENTAGES

Area ID	Area ha	Pre-Development Impervious %	Post-Development Impervious %
4-1	0.37	35	35
4-2	0.41	62	62
4-3	0.78	30	30
4-4	2.41	14	14
4-5	1.72	48	48
4-6	23.45	24	32
4-7	1.13	24	24
4-8	4.89	20	20
4-9	13.46	3	9
4-10	3.96	36	36
4-11	0.84	29	29
4-12	2.45	7	8
4-13	5.91	2	13
4-14	28.91	4	5
4-15	3.42	6	6
4-16	11.73	0	0

TABLE F-5
PIPE CREEK SUBCATCHMENTS
IMPERVIOUS PERCENTAGES

Area ID	Area ha	Pre-Development Impervious %	Post-Development Impervious %
5-1	0.36	53	53
5-2	0.64	43	43
5-3	1.23	15	15
5-4	4.16	10	10
5-5	1.93	29	29
5-6	3.55	28	28
5-7	1.05	36	36
5-8	0.99	30	30
5-9	1.10	37	37
5-10	0.92	27	27
5-11	3.13	4	8
5-12	18.00	2	2
5-13	3.04	1	5
5-14	17.34	4	4
5-15	5.55	4	4
5-16	13.89	0	0
5-17	2.74	5	7
5-18	1.99	24	24
5-19	3.45	33	33
5-20	0.43	38	38
5-21	0.34	47	47
5-22	0.56	30	30
5-23	7.22	10	10
5-24	3.39	14	14
5-25	2.74	11	34
5-26	4.20	2	30
5-27	7.08	3	15
5-28	0.83	8	15
5-29	1.88	5	6
5-30	27.01	3	3
5-31	1.45	26	26
5-32	3.13	40	40
5-33	0.90	42	42
5-34	0.88	24	24
5-35	0.27	38	38
5-36	3.86	1	15
5-37	14.01	3	3
5-38	1.51	6	6
5-39	1.84	40	40
5-40	0.84	45	45
5-41	1.56	25	25
5-42	2.27	0	29