Initial Environmental Examination Report

PUBLIC

Project Number: 56344-001
Draft
November 2023

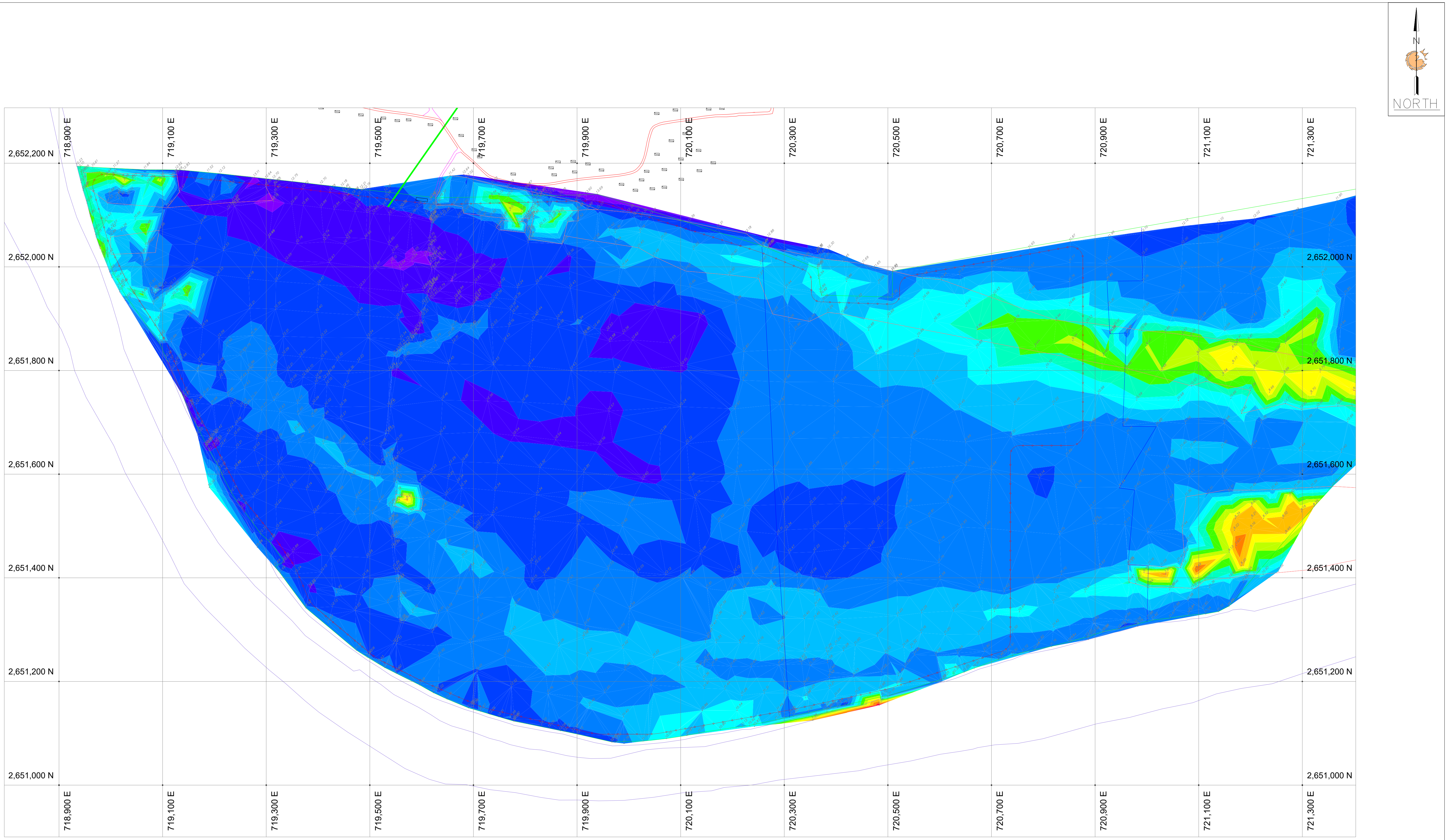
Bangladesh: Paramount Solar Power Project

PART 5: Annexure

Prepared by Dynamic Sun Energy Private Limited for the Asian Development Bank (ADB).

Figure 1

Topographic map



LEGEND

———	COORDINATE LINE REFERENCE
—×—×—	PROJECT BOUNDARY/FENCE
———	BOUNDARY LINE
⊗ X.XXX	GROUND LEVEL

Elevation Table

Number	Min. Depth (m.)	Max. Depth (m.)	Color
1	7.039	7.500	🟥
2	7.500	8.000	🟧
3	8.000	8.500	🟧
4	8.500	9.000	🟨
5	9.000	9.500	🟩
6	9.500	10.000	🟩
7	10.000	10.500	🟩
8	10.500	11.000	🟦
9	11.000	11.500	🟦
10	11.500	12.000	🟦
11	12.000	12.500	🟦
12	12.500	13.000	🟪
13	13.000	13.693	🟪

REV	DATE	DESCRIPTION	DRAWN	CHECKED	APPROVED
0	Aug / 25 / 2022	PRELIMINARY	SUEBPHONG	WANAGORN	POOSIT สย.3489

PROJECT :
100MW (AC) SOLAR PARK,
BHABANIPUR, PABNA.

OWNER :
DYNAMIC SUN ENERGY
PRIVATE LIMITED

CONTRACTOR :

EPC :

DESIGN :
บริษัท อินฟราเทค เอ็นเนอร์ยี่ จำกัด
Infratech Energy Co.,Ltd.
Infratech Energy Co., Ltd.
1032/217 Pahonyothin
18/1 RD. Jatujak District,
Bangkok 10900,Thailand
www.infratechenergy.com

DRAWING TITLE :
KEY PLAN FOR TOPOGRAPHIC SURVEY

PROJECT DOCUMENT NO :

DRAWING NO : TP-1

SCALE : 1 : 7,500
PAPER : A3 (m.)
SHEET : 1 / 1

Figure 2

Data from the river gauge at Harding bridge station

39.Padma/ Ganges at 90 Hardinge Bridge station

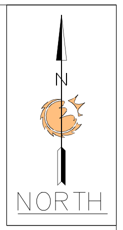
Recorded Maximum Discharge In Cusecs					Recorded Minimum Discharge In Cusecs					Remarks
Year	Discharge In Cusecs	Water Level M.W.L		Date & Year	Year	Discharge In Cusecs	Water Level M.W.L		Date & Year	
		(M)	(Ft)				(M)	(Ft)		
1	2	3	4	5	6	7	8	9	10	11
1972	1205352	13.26	43.49	6/9/1972	1972	73202	6.78	22.24	26/04/72	
1973	1585324	13.87	45.51	1/8/1973	1973	73825	6.52	21.39	2/5/1973	
1974	966772	12.74	41.80	26/09/1974	1974	67174	6.75	22.15	21/03/74	
1975	1752437	14.08	46.20	1/8/1975	1975	49865	6.17	20.23	5/5/1975	
1976	1814085	14.25	46.75	20/09/1976	1976	22868	5.03	16.5	29/03/1976	
1977	1734722	14.05	46.08	22/08/1977	1977	28159	6.23	20.43	21/03/1977	
1978	2027121	14.60	47.90	24/08/1978	1978	42844	6.19	20.30	25/03/1978	
1979	1288530	13.60	44.62	1/8/1979	1979	40223	6.23	20.45	6/4/1979	
1980	2050262	14.84	48.70	20/08/1980	1980	30567	6.22	20.4	5/5/1980	
1981	1899813	14.01	45.98	6/8/1981	1981	31141	6.13	20.12	8/4/1981	
1982	2129287	14.60	47.90	8/9/1982	1982	41197	5.86	19.23	29/03/1982	
1983	2042261	14.69	48.18	20/09/1983	1983	24733	5.38	17.65	8/4/1983.	
1984	1992069	14.48	47.52	17/09/1984	1984	31354	6.07	19.91	4/4/1984	
1985	1691925	13.98	45.88	23/10/1985	1985	24345	5.68	18.63	6/4/1985	
1986	1799424	14.11	46.29	7/8/1986	1986	40134	5.99	19.65	6/4/1986	
1987	2685118	14.80	48.57	19/09/1987	1987	30517	5.86	19.23	19/03/1987	
1988	2484918	14.87	48.77	2/9/1988	1988	31413	6.26	20.54	2/4/1988	
1989	1116147	13.19	43.27	8/9/1989	1989	15478	5.49	18.01	27/3/1989	
1990	1761470	13.95	45.77	20/08/1990	1990	19739	5.00	16.41	14/02/1990	
1991	1944222	14.62	47.98	14/09/1991	1991	18633	5.06	16.60	1/4/1991	
1992	1474385	13.67	44.86	21/09/1992	1992	13521	4.76	15.63	28/09/1992	
1993	1579445	13.74	45.09	22/09/1993	**1993**	**9218**	**4.24**	**13.91**	**30/03/1993**	
1994	1615018	14.22	46.64	19/08/1994	1994	14338	4.90	16.09	21/04/1994	
1995	1718239	13.76	45.13	18/08/1995	1995	12825	4.65	15.26	26/04/1995	
1996	1924221	14.50	47.56	4/9/1996	1996	14696	4.69	15.39	18/04/1996	
1997	1409644	13.73	45.05	8/9/1997	1997	6457	5.19	17.04	27/03/1997	
1998	**2581199**	**15.19**	**49.84**	**10/9/1998**	1998	36631	5.21	17.09	29/03/1998	

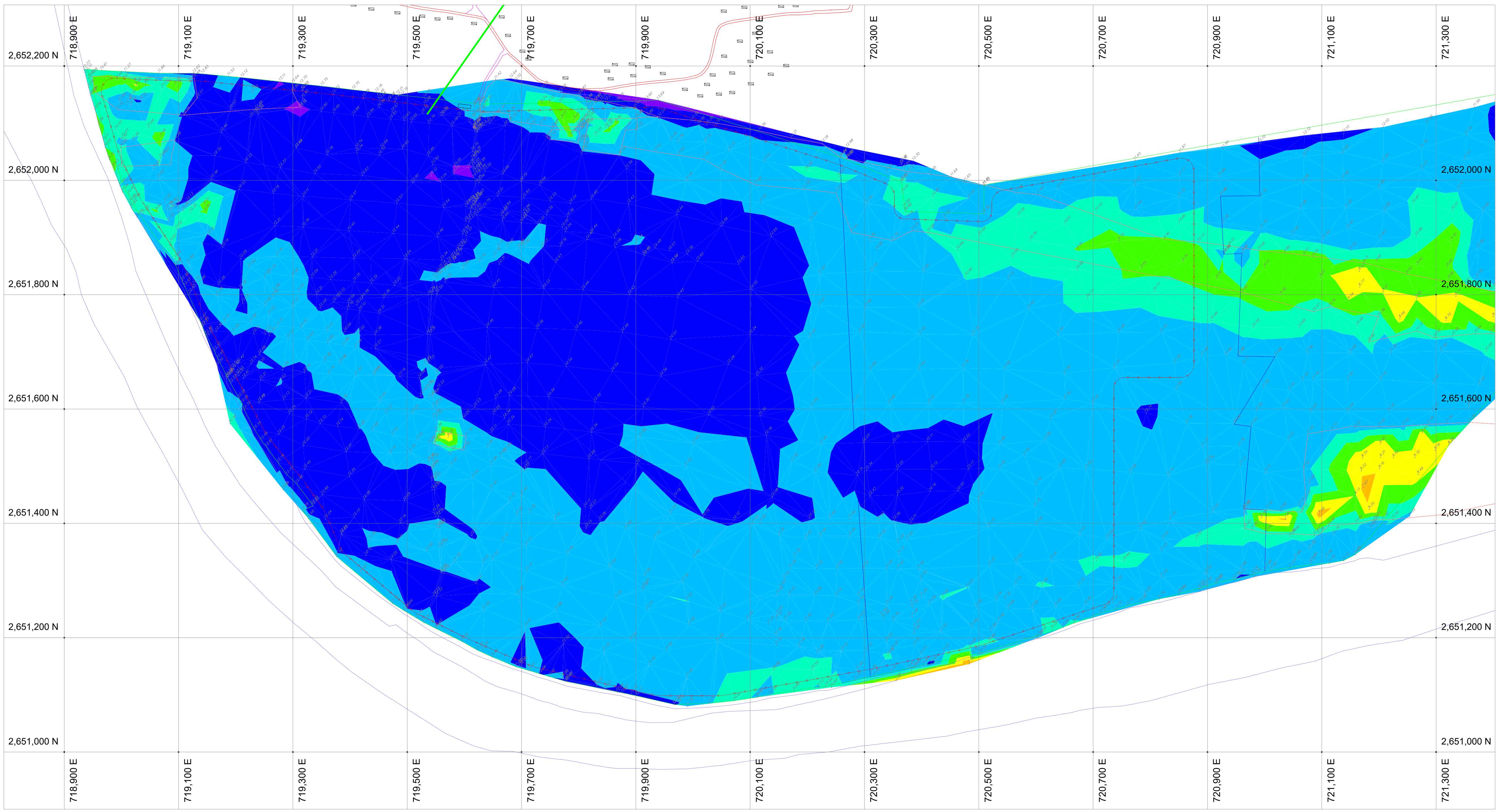
Harding's bridge : D.L = 14.25

Recorded Maximum Discharge In Cusecs					Recorded Minimum Discharge In Cusecs					Remarks
Year	Discharge In Cusecs	Water Level M.W.L		Date & Year	Year	Discharge In Cusecs	Water Level M.W.L		Date & Year	
		(M)	(Ft)				(M)	(Ft)		
	2	3	4	5	6	7	8	9	10	11
1999	2158530	12.93	42.41	29/09/1999	1999	27749	5.06	16.60	20/04/1999	
2000	2130219	14.19	46.57	24/09/2000	2000	33712	5.33	17.50	25/08/2000	
2001	1886078	13.90	45.60	31/08/2001	2001	20522	4.71	15.44	21/04/2001	
2002	1447224	13.23	43.42	26/08/2002	2002	32267	5.28	17.31	31/03/2002	
2003	2114493	14.28	46.85	20/09/2003	2003	31737	5.55	18.21	20/04/2003	
2004	1331569	13.61	44.65	26/07/2004	2004	31670	5.71	18.73	29/03/2004	
2005	1540427	13.76	45.14	31/08/2005	2005	23379	5.31	17.42	30/03/2005	
2006	1315625	13.34	43.77	1/9/2006	2006	20049	4.86	15.94	20/04/2006	Bhobanipur, pabna
2007	1914650	14.00	45.93	6/8/2007	2007	40415	5.73	18.80	28/03/2007	D.L = 13.25 m(PWD)
2008	1785593	13.83	45.37	3/9/2008	2008	18353	5.36	17.59	21/04/2008	
2009	1363177	13.36	43.83	27/08/2009	2009	20490	5.64	18.5	22/04/2009	
2010	1422320	13.69	44.91	7/9/2010	2010	13849	4.73	15.52	2/4/2010	
2011	1719289	13.78	45.21	2/10/2011	2011	27050	5.30	17.39	20/04/2011	
2012	1563568	13.56	44.49	27/09/2012	2012	34197	5.15	16.90	28/03/2012	
2013	1914952	14.13	46.36	8/9/2013	2013	32894	5.38	17.65	16/04/2013	
2014	1533069	13.31	43.67	23/08/2014	2014	48923	5.41	17.75	14/5/2014	
2015	1648455	13.75	45.11	28/08/2015	2015	47103	4.92	16.14	12/3/2015	
2016	1982374	14.16	46.46	27/08/2016	2016	15394	4.26	13.98	28/03/2016	
2017	1731646	13.845	45.42	21/08/2017	2017	26012	4.76	15.62	29/03/2017	
2018	1429509	13.450	44.13	10/9/2018	2018	33004	4.46	14.63	17/04/2018	
2019	1992601	14.330	47.01	3/10/2019	2019	31217	4.56	14.96	3/4/2019	
2020	1600623	13.500	44.29	29/07/2020	2020	48009	5.34	17.52	4/3/2020	
2021	1991470	14.200	46.59	21/08/2021	2021	20623	4.13	13.55	9/5/2021	

Figure 3

Flood depth on-site from 100 years ARI with the effect of climate change





LEGEND

COORDINATE LINE REFERENCE

PROJECT BOUNDARY/FENCE

BOUNDARY LINE

◎ X.XXX GROUND LEVEL

FLOOD DEPTH Table
From Flood EL.15.04 m.

Number	Min. Depth cut/fill (m.)	Max. Depth cut/fill (m.)	Color
1	1.000	2.000	🟪
2	2.000	3.000	🟦
3	3.000	4.000	🟦
4	4.000	5.000	🟩
5	5.000	6.000	🟩
6	6.000	7.000	🟨
7	7.000	8.000	🟧
8	8.000	9.000	🟥

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0	Aug / 25 / 2022	PRELIMINARY	SUEBPHONG	WANAGORN	POOSIT สย.3489

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Infratech Energy Co., Ltd.
1032/217 Pahonyothin
18/1 RD. Jatujak District,
Bangkok 10900,Thailand
www.infratechenergy.com

DRAWING TITLE :
LAYOUT FOR FLOOD DEPTH

PROJECT DOCUMENT NO :

DRAWING NO : FD–1

SCALE : 1 : 7,500
PAPER : A3 (m.)
SHEET : 1 / 1

Figure 4

Rainfall data from 3 rainfall stations covering the project site

Rainfall Station

Rainall Station No.	Lat	Long	Upazila	District
1	24.016449	89.262932	Pabna Sadar	Pabna
2	23.839301	89.151114	Kushtia Sadar	Kushtia
3	24.065274	89.030285	Ishwardi	Pabna

Station :	1	Lat :	24.016449
Duration :	2007-2021	Long:	89.262932

Year	Maximum Daily Rainfall
	mm
2007	126.90
2008	93.18
2009	96.63
2010	74.60
2011	121.09
2012	40.05
2013	61.23
2014	135.03
2015	176.40
2016	74.75
2017	78.28
2018	62.57
2019	43.90
2020	108.72
2021	74.82

Station : 2
Duration : 2007-2021

Lat : 23.839301
Long: 89.151114

Year	Maximum Daily Rainfall
	mm
2007	111.16
2008	96.59
2009	69.53
2010	52.43
2011	163.83
2012	51.61
2013	37.67
2014	74.95
2015	154.83
2016	52.98
2017	78.30
2018	53.22
2019	65.11
2020	113.46
2021	80.69

Station :	3	Lat :	24.065274
Duration :	2007-2021	Long:	89.030285

Year	Maximum Daily Rainfall
	mm
2007	104.89
2008	88.51
2009	64.58
2010	58.22
2011	152.25
2012	87.99
2013	42.86
2014	118.04
2015	189.62
2016	71.87
2017	64.68
2018	63.01
2019	116.16
2020	71.66
2021	76.44

Annex A

Flood Analysis from Padma river

Annex A-1

Flood level of Padma river by Gumbel method


Legend
100 Mwac Dynamic Sun
Damukdia
Hardinge Bridge Station
Ruppur রূপপুর
Farakpur
Pabna পাবনা
Dwipchar
Talbaria Station
100 Mwac Dynamic Sun
Mirpur মিরপুর
Google Earth
6 km
N

Frequency Analysis of Maximum Annual Water Level of Hardinge Bridge station

Station :	Hardinge Bridge	River:	Ganges-Padma
District :	Pabna	Country :	Bangladesh

Year	WLmax (m)
1972	13.26
1973	13.87
1974	12.74
1975	14.08
1976	14.25
1977	14.05
1978	14.6
1979	13.6
1980	14.84
1981	14.01
1982	14.6
1983	14.69
1984	14.48
1985	13.98
1986	14.11
1987	14.8
1988	14.87
1989	13.19
1990	13.95
1991	14.62
1992	13.67
1993	13.74
1994	14.22
1995	13.76
1996	14.5
1997	13.73
1998	15.19
1999	12.93
2000	14.19
2001	13.9
2002	13.23
2003	14.28
2004	13.61
2005	13.76
2006	13.34
2007	14
2008	13.83
2009	13.36
2010	13.69
2011	13.78
2012	13.56
2013	14.13
2014	13.31
2015	13.75
2016	14.16
2017	13.845
2018	13.45
2019	14.33
2020	13.5
2021	14.2

Result of Gumbel Distribution Analysis

No.	Year	WLmax (m)	(Xi-X̄)	(Xi-X̄)^2
1	1972	13.26	-0.6907	0.4771
2	1973	13.87	-0.0807	0.0065
3	1974	12.74	-1.2107	1.4658
4	1975	14.08	0.1293	0.0167
5	1976	14.25	0.2993	0.0896
6	1977	14.05	0.0993	0.0099
7	1978	14.60	0.6493	0.4216
8	1979	13.60	-0.3507	0.1230
9	1980	14.84	0.8893	0.7909
10	1981	14.01	0.0593	0.0035
11	1982	14.60	0.6493	0.4216
12	1983	14.69	0.7393	0.5466
13	1984	14.48	0.5293	0.2802
14	1985	13.98	0.0293	0.0009
15	1986	14.11	0.1593	0.0254
16	1987	14.80	0.8493	0.7213
17	1988	14.87	0.9193	0.8451
18	1989	13.19	-0.7607	0.5787
19	1990	13.95	-0.0007	0.0000
20	1991	14.62	0.6693	0.4480
21	1992	13.67	-0.2807	0.0788
22	1993	13.74	-0.2107	0.0444
23	1994	14.22	0.2693	0.0725
24	1995	13.76	-0.1907	0.0364
25	1996	14.50	0.5493	0.3017
26	1997	13.73	-0.2207	0.0487
27	1998	15.19	1.2393	1.5359
28	1999	12.93	-1.0207	1.0418
29	2000	14.19	0.2393	0.0573
30	2001	13.90	-0.0507	0.0026
31	2002	13.23	-0.7207	0.5194
32	2003	14.28	0.3293	0.1084
33	2004	13.61	-0.3407	0.1161
34	2005	13.76	-0.1907	0.0364
35	2006	13.34	-0.6107	0.3730
36	2007	14.00	0.0493	0.0024
37	2008	13.83	-0.1207	0.0146
38	2009	13.36	-0.5907	0.3489
39	2010	13.69	-0.2607	0.0680
40	2011	13.78	-0.1707	0.0291
41	2012	13.56	-0.3907	0.1526
42	2013	14.13	0.1793	0.0321
43	2014	13.31	-0.6407	0.4105
44	2015	13.75	-0.2007	0.0403
45	2016	14.16	0.2093	0.0438
46	2017	13.85	-0.1057	0.0112
47	2018	13.45	-0.5007	0.2507
48	2019	14.33	0.3793	0.1439
49	2020	13.50	-0.4507	0.2031
50	2021	14.20	0.2493	0.0622
Sum		697.54	0.00	13.46
Average, X̄		13.9507		
Yn		0.5485		
Sn		1.1607		
Standard Deviation, Sd		0.5241		

Result of Peak Water Level Calculation using Gumbel Distribution Analysis

No.	X̄	Sn	Yn	Sd	Tr	Yt	K	WLmax(design) m
								XT = X̄ + K(Sd)
1	13.9507	1.1607	0.5485	0.5241	2	0.3665	-0.1568	13.869
2	13.9507	1.1607	0.5485	0.5241	5	1.4999	0.8197	14.380
3	13.9507	1.1607	0.5485	0.5241	10	2.2504	1.4662	14.719
4	13.9507	1.1607	0.5485	0.5241	25	3.1985	2.2831	15.147
5	13.9507	1.1607	0.5485	0.5241	50	3.9019	2.8892	15.465
6	13.9507	1.1607	0.5485	0.5241	100	4.6001	3.4907	15.780

equation (1)

$$S.D. = \sqrt{\frac{\sum (x_i - \bar{x})^2}{(n-1)}}$$

where

Sd = the standard deviation
n = the number of sample
Xi = the each value of the sample
X̄ = the mean value of this sample.

XT = X̄ + K(Sd)

equation (2)

where

XT = Gumbel’s Distribution in reference to return period
X̄ = the mean value
Sd = the standard deviation
K = the factor of frequency in Gumbel method

$$K = \frac{Y_T - \overline{Y_n}}{S_n}$$

equation (3)

where

Y_T = the reduced variate which is calculated by using the equation (4)
the Sn and Yn value have been used from Gumbel’s extreme value distribution chart that depends on the sample size.

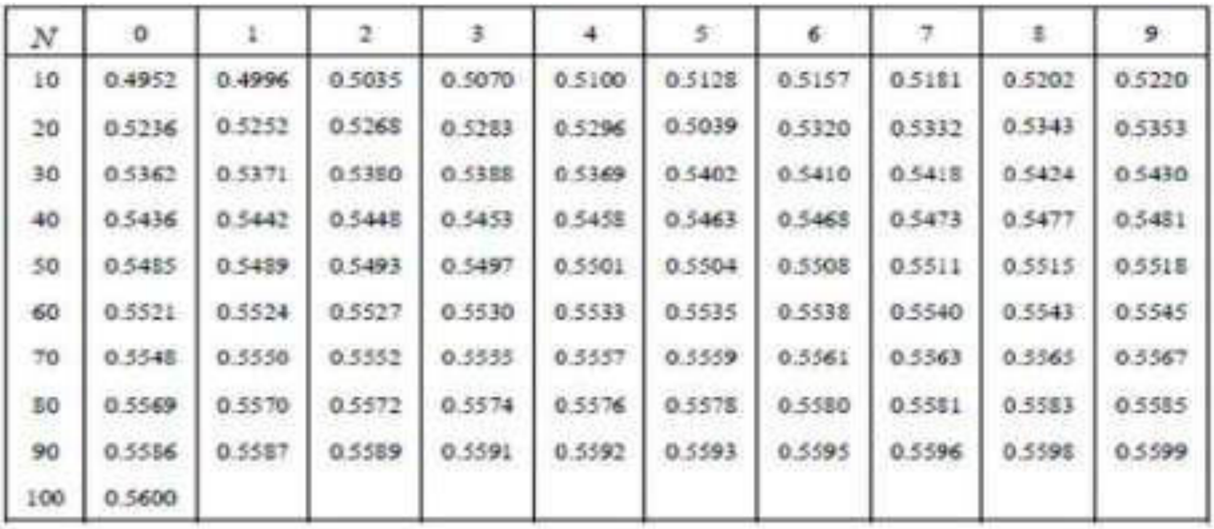
$$Y_T = -\left[\mathrm{Ln.Ln.}\left(\frac{T}{T-1}\right)\right]$$

equation (4)

where

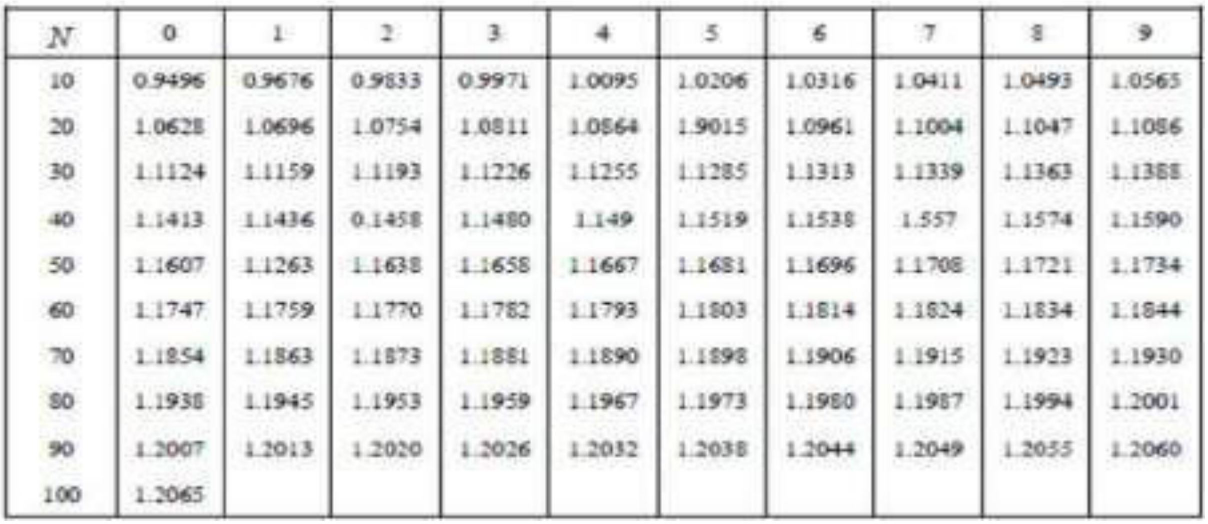
T = the predicted time period.

Table 1: Yn



N	0	1	2	3	4	5	6	7	8	9
10	0.4952	0.4996	0.5035	0.5070	0.5100	0.5128	0.5157	0.5181	0.5202	0.5220
20	0.5236	0.5252	0.5268	0.5283	0.5296	0.5039	0.5320	0.5332	0.5343	0.5353
30	0.5362	0.5371	0.5380	0.5388	0.5369	0.5402	0.5410	0.5418	0.5424	0.5430
40	0.5436	0.5442	0.5448	0.5453	0.5458	0.5463	0.5468	0.5473	0.5477	0.5481
50	0.5485	0.5489	0.5493	0.5497	0.5501	0.5504	0.5508	0.5511	0.5515	0.5518
60	0.5521	0.5524	0.5527	0.5530	0.5533	0.5535	0.5538	0.5540	0.5543	0.5545
70	0.5548	0.5550	0.5552	0.5555	0.5557	0.5559	0.5561	0.5563	0.5565	0.5567
80	0.5569	0.5570	0.5572	0.5574	0.5576	0.5578	0.5580	0.5581	0.5583	0.5585
90	0.5586	0.5587	0.5589	0.5591	0.5592	0.5593	0.5595	0.5596	0.5598	0.5599
100	0.5600									

Table 2: Sn



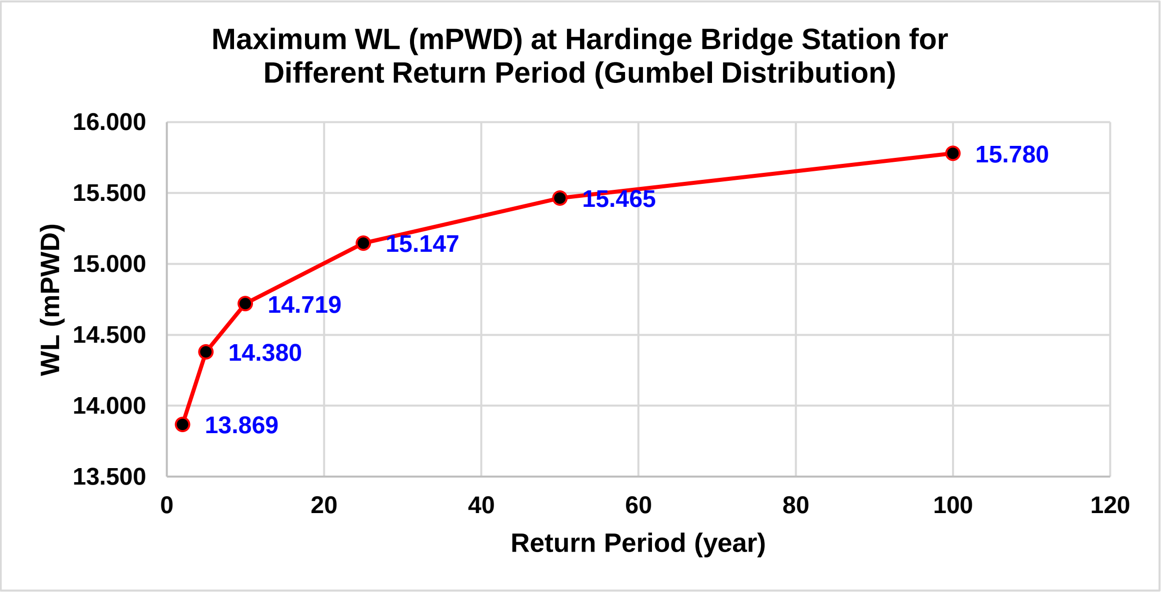
N	0	1	2	3	4	5	6	7	8	9
10	0.9496	0.9676	0.9833	0.9971	1.0095	1.0206	1.0316	1.0411	1.0493	1.0565
20	1.0628	1.0696	1.0754	1.0811	1.0864	1.9015	1.0961	1.1004	1.1047	1.1086
30	1.1124	1.1159	1.1193	1.1226	1.1255	1.1285	1.1313	1.1339	1.1363	1.1388
40	1.1413	1.1436	0.1458	1.1480	1.149	1.1519	1.1538	1.557	1.1574	1.1590
50	1.1607	1.1263	1.1638	1.1658	1.1667	1.1681	1.1696	1.1708	1.1721	1.1734
60	1.1747	1.1759	1.1770	1.1782	1.1793	1.1803	1.1814	1.1824	1.1834	1.1844
70	1.1854	1.1863	1.1873	1.1881	1.1890	1.1898	1.1906	1.1915	1.1923	1.1930
80	1.1938	1.1945	1.1953	1.1959	1.1967	1.1973	1.1980	1.1987	1.1994	1.2001
90	1.2007	1.2013	1.2020	1.2026	1.2032	1.2038	1.2044	1.2049	1.2055	1.2060
100	1.2065									

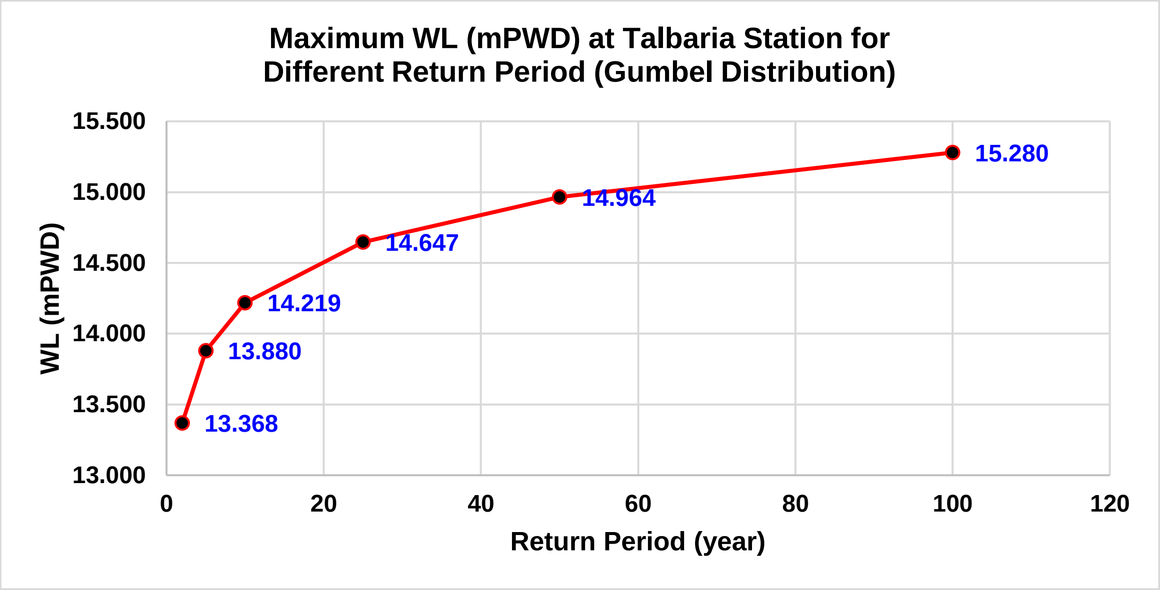
The design HWL at each ARI at the Talbaria station is calculated below.

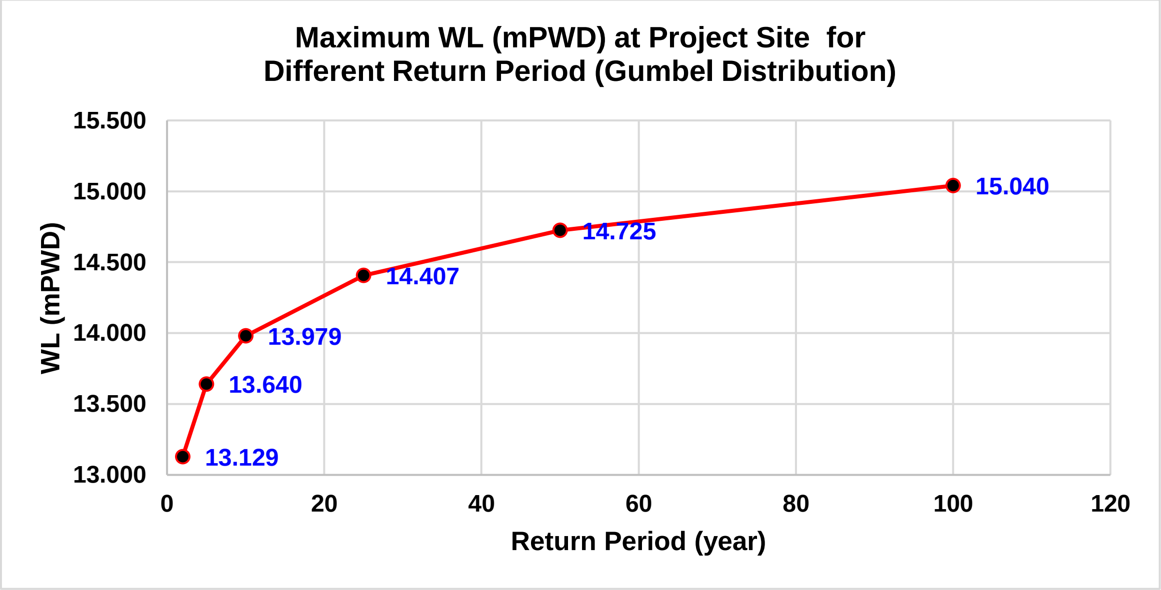
Hardinge Bridge station to Talbaria station	14300	m	14.3	km
Slope	0.000035	m/m		
Tr	WL(Max)_Hardinge Bridge	(Slope x L)	WL(Max)_Talbaria	
WL 2YR	13.869	0.501	13.368	
WL 5YR	14.380	0.501	13.880	
WL 10YR	14.719	0.501	14.219	
WL 25YR	15.147	0.501	14.647	
WL 50YR	15.465	0.501	14.964	
WL 100YR	15.780	0.501	15.280	

The design HWL at each ARI at the Project site is calculated below.

Talbaria station to Project site	6840	m	6.84	km
Slope	0.000035	m/m		
Tr	WL(Max)_Talbaria	(Slope x L)	WL(Max)_Site	
WL 2YR	13.368	0.239	13.129	
WL 5YR	13.880	0.239	13.640	
WL 10YR	14.219	0.239	13.979	
WL 25YR	14.647	0.239	14.407	
WL 50YR	14.964	0.239	14.725	
WL 100YR	15.280	0.239	15.040	




Maximum WL (mPWD) at Talbaria Station for
Different Return Period (Gumbel Distribution)
15.500
15.000
14.500
14.000
13.500
13.000
WL (mPWD)
0
20
40
60
80
100
120
Return Period (year)
13.368
13.880
14.219
14.647
14.964
15.280


Maximum WL (mPWD) at Project Site for
Different Return Period (Gumbel Distribution)
15.500
15.000
14.500
14.000
13.500
13.000
WL (mPWD)
0
20
40
60
80
100
120
Return Period (year)
13.129
13.640
13.979
14.407
14.725
15.040

Annex A-2

Flood level of Padma river by Log Pearson Type III method


Damukdia
Hardinge Bridge Station
Ruppur রূপপুর
Farakpur
Talbaria Station
100 Mwac Dynamic Sun
Mirpur মি রপুর
Pabna পাবনা
Dwipchar
Legend
100 Mwac Dynamic Sun
Google Earth
6 km
N

Frequency Analysis of Maximum Annual Water Level of Hardinge Bridge station

Station :	Hardinge Bridge	River:	Ganges-Padma
District :	Pabna	Country :	Bangladesh

Year	WLmax (m)
1972	13.26
1973	13.87
1974	12.74
1975	14.08
1976	14.25
1977	14.05
1978	14.6
1979	13.6
1980	14.84
1981	14.01
1982	14.6
1983	14.69
1984	14.48
1985	13.98
1986	14.11
1987	14.8
1988	14.87
1989	13.19
1990	13.95
1991	14.62
1992	13.67
1993	13.74
1994	14.22
1995	13.76
1996	14.5
1997	13.73
1998	15.19
1999	12.93
2000	14.19
2001	13.9
2002	13.23
2003	14.28
2004	13.61
2005	13.76
2006	13.34
2007	14
2008	13.83
2009	13.36
2010	13.69
2011	13.78
2012	13.56
2013	14.13
2014	13.31
2015	13.75
2016	14.16
2017	13.845
2018	13.45
2019	14.33
2020	13.5
2021	14.2

Result of Log Pearson Type III Distribution Analysis

No.	Year	WLmax (m)	Log Y	Log Ȳ	Log Y-Log Ȳ	(Log Y-Log Ȳ)^2	(Log Y-Log Ȳ)^3
1	1972	13.26	1.1225	1.1443	-0.0218	0.0005	0.0000
2	1973	13.87	1.1421	1.1443	-0.0022	0.0000	0.0000
3	1974	12.74	1.1052	1.1443	-0.0391	0.0015	-0.0001
4	1975	14.08	1.1486	1.1443	0.0043	0.0000	0.0000
5	1976	14.25	1.1538	1.1443	0.0095	0.0001	0.0000
6	1977	14.05	1.1477	1.1443	0.0034	0.0000	0.0000
7	1978	14.60	1.1644	1.1443	0.0201	0.0004	0.0000
8	1979	13.60	1.1335	1.1443	-0.0108	0.0001	0.0000
9	1980	14.84	1.1714	1.1443	0.0271	0.0007	0.0000
10	1981	14.01	1.1464	1.1443	0.0021	0.0000	0.0000
11	1982	14.60	1.1644	1.1443	0.0201	0.0004	0.0000
12	1983	14.69	1.1670	1.1443	0.0227	0.0005	0.0000
13	1984	14.48	1.1608	1.1443	0.0165	0.0003	0.0000
14	1985	13.98	1.1455	1.1443	0.0012	0.0000	0.0000
15	1986	14.11	1.1495	1.1443	0.0052	0.0000	0.0000
16	1987	14.80	1.1703	1.1443	0.0260	0.0007	0.0000
17	1988	14.87	1.1723	1.1443	0.0280	0.0008	0.0000
18	1989	13.19	1.1202	1.1443	-0.0241	0.0006	0.0000
19	1990	13.95	1.1446	1.1443	0.0003	0.0000	0.0000
20	1991	14.62	1.1649	1.1443	0.0207	0.0004	0.0000
21	1992	13.67	1.1358	1.1443	-0.0085	0.0001	0.0000
22	1993	13.74	1.1380	1.1443	-0.0063	0.0000	0.0000
23	1994	14.22	1.1529	1.1443	0.0086	0.0001	0.0000
24	1995	13.76	1.1386	1.1443	-0.0057	0.0000	0.0000
25	1996	14.50	1.1614	1.1443	0.0171	0.0003	0.0000
26	1997	13.73	1.1377	1.1443	-0.0066	0.0000	0.0000
27	1998	15.19	1.1816	1.1443	0.0373	0.0014	0.0001
28	1999	12.93	1.1116	1.1443	-0.0327	0.0011	0.0000
29	2000	14.19	1.1520	1.1443	0.0077	0.0001	0.0000
30	2001	13.90	1.1430	1.1443	-0.0013	0.0000	0.0000
31	2002	13.23	1.1216	1.1443	-0.0227	0.0005	0.0000
32	2003	14.28	1.1547	1.1443	0.0104	0.0001	0.0000
33	2004	13.61	1.1339	1.1443	-0.0104	0.0001	0.0000
34	2005	13.76	1.1386	1.1443	-0.0057	0.0000	0.0000
35	2006	13.34	1.1252	1.1443	-0.0191	0.0004	0.0000
36	2007	14.00	1.1461	1.1443	0.0018	0.0000	0.0000
37	2008	13.83	1.1408	1.1443	-0.0035	0.0000	0.0000
38	2009	13.36	1.1258	1.1443	-0.0185	0.0003	0.0000
39	2010	13.69	1.1364	1.1443	-0.0079	0.0001	0.0000
40	2011	13.78	1.1392	1.1443	-0.0050	0.0000	0.0000
41	2012	13.56	1.1323	1.1443	-0.0120	0.0001	0.0000
42	2013	14.13	1.1501	1.1443	0.0058	0.0000	0.0000
43	2014	13.31	1.1242	1.1443	-0.0201	0.0004	0.0000
44	2015	13.75	1.1383	1.1443	-0.0060	0.0000	0.0000
45	2016	14.16	1.1511	1.1443	0.0068	0.0000	0.0000
46	2017	13.85	1.1413	1.1443	-0.0030	0.0000	0.0000
47	2018	13.45	1.1287	1.1443	-0.0156	0.0002	0.0000
48	2019	14.33	1.1562	1.1443	0.0120	0.0001	0.0000
49	2020	13.50	1.1303	1.1443	-0.0140	0.0002	0.0000
50	2021	14.20	1.1523	1.1443	0.0080	0.0001	0.0000
Sum			57.2148	57.2148	0.0000	0.0130	0.0000
Average, Ȳ			1.1443				
Coefficient of skew, Cw			-0.0094				
Standard Deviation, Sd			0.0163				

Result of Peak Water Level Calculation using Log Pearson Type III Distribution Analysis

No.	Tr	Log $\bar{Y}$	Sd	P	K	$Y_T = \bar{Y} + K(Sd)$	WLmax(design) m
				%			$XT= 10^{YT}$
1	2	1.1443	0.0163	50	0.0016	1.1443	13.942
2	5	1.1443	0.0163	20	0.8424	1.1580	14.389
3	10	1.1443	0.0163	10	1.2809	1.1652	14.628
4	25	1.1443	0.0163	4	1.7477	1.1728	14.887
5	50	1.1443	0.0163	2	2.0489	1.1777	15.056
6	100	1.1443	0.0163	1	2.3191	1.1821	15.210

$$\boxed{Sd = \sqrt{\frac{\sum(\text{Log } Y-\text{Log } \bar{Y})^2}{n-1}}} \qquad \text{equation (1)}$$

where Sd = standard deviation (in the log form)
n = the number of sample
Log Y= the each value of the sample (in the log form)
Log $\bar{Y}$ = the mean value of this sample (in the log form)

$$\boxed{YT = \bar{Y} + K(Sd)} \qquad \text{equation (2)}$$

where YT = the predicted value of log X
$\bar{Y}$ = average of the logarithms of X
Sd = standard deviation of the logarithms.
K = the factor of frequency in Log Pearson Type III method
function of the skewness coefficient and return period and can be found using the frequency factor table.

$$\boxed{XT= 10^{YT}} \qquad \text{equation (3)}$$

where XT = the computed peak water level for log-Pearson Type III.

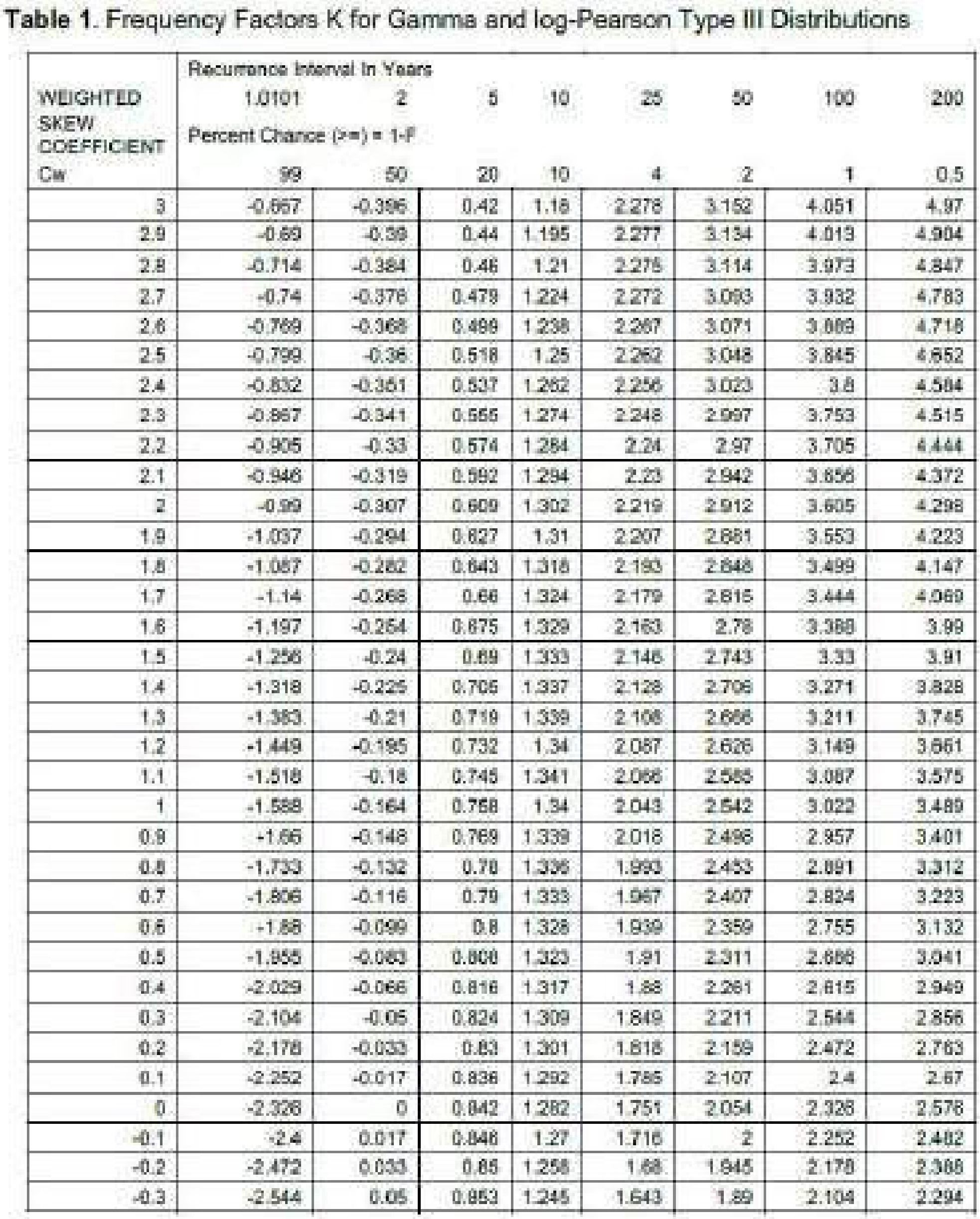


Table 1. Frequency Factors K for Gamma and log-Pearson Type III Distributions

WEIGHTED SKEW COEFFICIENT	Recurrence Interval In Years							
	1.0101	2	5	10	25	50	100	200
	Percent Chance (>=) = 1-F							
Cw	99	50	20	10	4	2	1	0.5
3	-0.667	-0.396	0.42	1.18	2.278	3.152	4.051	4.97
2.9	-0.69	-0.39	0.44	1.195	2.277	3.134	4.013	4.904
2.8	-0.714	-0.384	0.46	1.21	2.275	3.114	3.973	4.847
2.7	-0.74	-0.376	0.479	1.224	2.272	3.093	3.932	4.783
2.6	-0.769	-0.368	0.499	1.238	2.267	3.071	3.889	4.718
2.5	-0.799	-0.36	0.518	1.25	2.262	3.048	3.845	4.652
2.4	-0.832	-0.351	0.537	1.262	2.256	3.023	3.8	4.584
2.3	-0.867	-0.341	0.555	1.274	2.248	2.997	3.753	4.515
2.2	-0.905	-0.33	0.574	1.284	2.24	2.97	3.705	4.444
2.1	-0.946	-0.319	0.592	1.294	2.23	2.942	3.656	4.372
2	-0.99	-0.307	0.609	1.302	2.219	2.912	3.605	4.298
1.9	-1.037	-0.294	0.627	1.31	2.207	2.881	3.553	4.223
1.8	-1.087	-0.282	0.643	1.318	2.193	2.848	3.499	4.147
1.7	-1.14	-0.268	0.66	1.324	2.179	2.815	3.444	4.069
1.6	-1.197	-0.254	0.675	1.329	2.163	2.78	3.388	3.99
1.5	-1.256	-0.24	0.69	1.333	2.146	2.743	3.33	3.91
1.4	-1.318	-0.225	0.705	1.337	2.128	2.706	3.271	3.828
1.3	-1.383	-0.21	0.719	1.339	2.108	2.666	3.211	3.745
1.2	-1.449	-0.195	0.732	1.34	2.087	2.626	3.149	3.661
1.1	-1.518	-0.18	0.745	1.341	2.066	2.585	3.087	3.575
1	-1.588	-0.164	0.758	1.34	2.043	2.542	3.022	3.489
0.9	-1.66	-0.148	0.769	1.339	2.018	2.498	2.957	3.401
0.8	-1.733	-0.132	0.78	1.336	1.993	2.453	2.891	3.312
0.7	-1.806	-0.116	0.79	1.333	1.967	2.407	2.824	3.223
0.6	-1.88	-0.099	0.8	1.328	1.939	2.359	2.755	3.132
0.5	-1.955	-0.083	0.808	1.323	1.91	2.311	2.686	3.041
0.4	-2.029	-0.066	0.816	1.317	1.88	2.261	2.615	2.949
0.3	-2.104	-0.05	0.824	1.309	1.849	2.211	2.544	2.856
0.2	-2.178	-0.033	0.83	1.301	1.818	2.159	2.472	2.763
0.1	-2.252	-0.017	0.836	1.292	1.785	2.107	2.4	2.67
0	-2.326	0	0.842	1.282	1.751	2.054	2.326	2.576
-0.1	-2.4	0.017	0.846	1.27	1.716	2	2.252	2.482
-0.2	-2.472	0.033	0.85	1.258	1.68	1.945	2.178	2.388
-0.3	-2.544	0.05	0.853	1.245	1.643	1.89	2.104	2.294

Table 1. Frequency Factors K for Gamma and log-Pearson Type III Distributions (Con.)

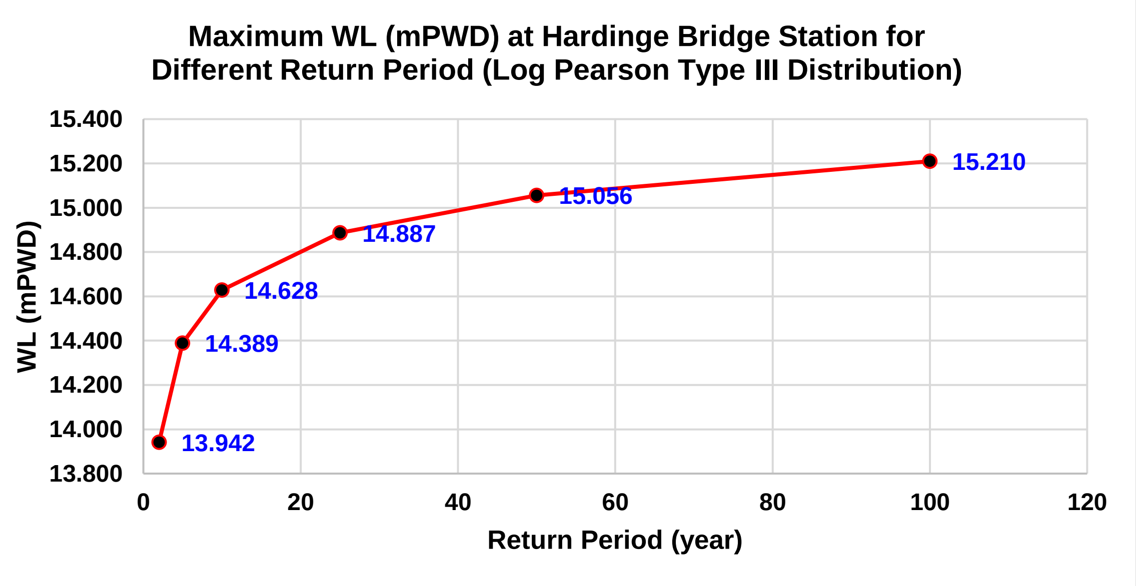
WEIGHTED SKEW COEFFICIENT Cw	Recurrence Interval In Years							
	1.0101	2	5	10	25	50	100	200
	Percent Chance (>=) = 1-F							
	99	50	20	10	4	2	1	0.5
-0.4	-2.615	0.066	0.855	1.231	1.606	1.834	2.029	2.201
-0.5	-2.686	0.083	0.856	1.216	1.567	1.777	1.955	2.108
-0.6	-2.755	0.099	0.857	1.2	1.528	1.72	1.88	2.016
-0.7	-2.824	0.116	0.857	1.183	1.488	1.663	1.806	1.926
-0.8	-2.891	0.132	0.856	1.166	1.448	1.606	1.733	1.837
-0.9	-2.957	0.148	0.854	1.147	1.407	1.549	1.66	1.749
-1	-3.022	0.164	0.852	1.128	1.366	1.492	1.588	1.664
-1.1	-3.087	0.18	0.848	1.107	1.324	1.435	1.518	1.581
-1.2	-3.149	0.195	0.844	1.086	1.282	1.379	1.449	1.501
-1.3	-3.211	0.21	0.838	1.064	1.24	1.324	1.383	1.424
-1.4	-3.271	0.225	0.832	1.041	1.198	1.27	1.318	1.351
-1.5	-3.33	0.24	0.825	1.018	1.157	1.217	1.256	1.282
-1.6	-3.88	0.254	0.817	0.994	1.116	1.166	1.197	1.216
-1.7	-3.444	0.268	0.808	0.97	1.075	1.116	1.14	1.155
-1.8	-3.499	0.282	0.799	0.945	1.035	1.069	1.087	1.097
-1.9	-3.553	0.294	0.788	0.92	0.996	1.023	1.037	1.044
-2	-3.605	0.307	0.777	0.895	0.959	0.98	0.99	0.995
-2.1	-3.656	0.319	0.765	0.869	0.923	0.939	0.946	0.949
-2.2	-3.705	0.33	0.752	0.844	0.888	0.9	0.905	0.907
-2.3	-3.753	0.341	0.739	0.819	0.855	0.864	0.867	0.869
-2.4	-3.8	0.351	0.725	0.795	0.823	0.83	0.832	0.833
-2.5	-3.845	0.36	0.711	0.711	0.793	0.798	0.799	0.8
-2.6	-3.899	0.368	0.696	0.747	0.764	0.768	0.769	0.769
-2.7	-3.932	0.376	0.681	0.724	0.738	0.74	0.74	0.741
-2.8	-3.973	0.384	0.666	0.702	0.712	0.714	0.714	0.714
-2.9	-4.013	0.39	0.651	0.681	0.683	0.689	0.69	0.69
-3	-4.051	0.396	0.636	0.66	0.666	0.666	0.667	0.667

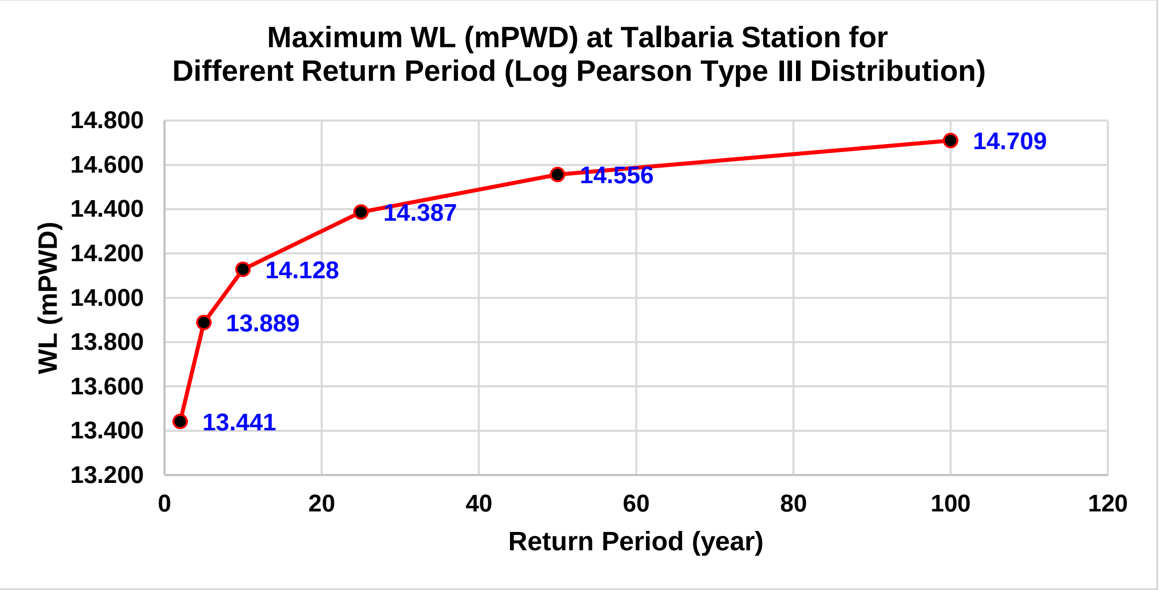
The design HWL at each ARI at the Talbaria station is calculated below.

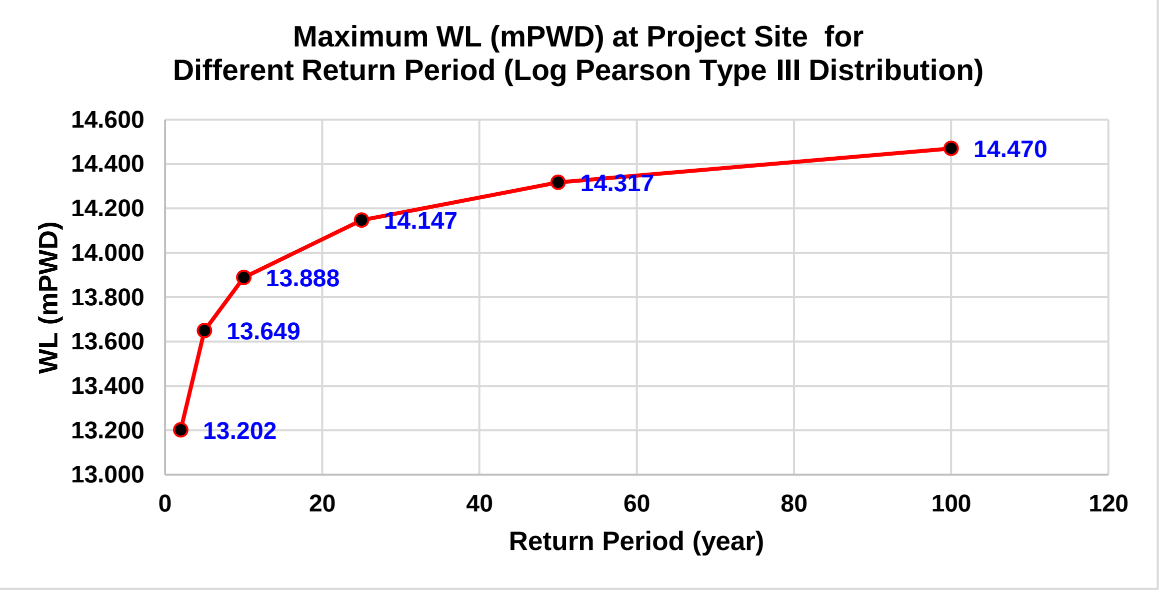
Hardinge Bridge station to Talbaria station	14300	m	14.3	km
Slope	0.000035	m/m		
Tr	WL(Max)_Hardinge Bridge	(Slope x L)	WL(Max)_Talbaria	
WL 2YR	13.942	0.501	13.441	
WL 5YR	14.389	0.501	13.889	
WL 10YR	14.628	0.501	14.128	
WL 25YR	14.887	0.501	14.387	
WL 50YR	15.056	0.501	14.556	
WL 100YR	15.210	0.501	14.709	

The design HWL at each ARI at the Project site is calculated below.

Talbaria station to Project site	6840	m	6.84	km
Slope	0.000035	m/m		
Tr	WL(Max)_Talbaria	(Slope x L)	WL(Max)_Site	
WL 2YR	13.441	0.239	13.202	
WL 5YR	13.889	0.239	13.649	
WL 10YR	14.128	0.239	13.888	
WL 25YR	14.387	0.239	14.147	
WL 50YR	14.556	0.239	14.317	
WL 100YR	14.709	0.239	14.470	


Maximum WL (mPWD) at Hardinge Bridge Station for Different Return Period (Log Pearson Type III Distribution)


Maximum WL (mPWD) at Talbaria Station for
Different Return Period (Log Pearson Type III Distribution)
WL (mPWD)
14.800
14.600
14.400
14.200
14.000
13.800
13.600
13.400
13.200
0
20
40
60
80
100
120
Return Period (year)
13.441
13.889
14.128
14.387
14.556
14.709


Maximum WL (mPWD) at Project Site for
Different Return Period (Log Pearson Type III Distribution)
WL (mPWD)
14.600
14.400
14.200
14.000
13.800
13.600
13.400
13.200
13.000
0
20
40
60
80
100
120
Return Period (year)
13.202
13.649
13.888
14.147
14.317
14.470

Annex B

Hydraulic Modeling
25, 50, 100 Year ARI from Overtopping of Padma River

(Pre Development Stage)

Annex B-1

Hydraulic Modeling set up from Overtopping of Padma river

1. MODEL SET UP

To assess the flood risk for this Solar Plant site under existing conditions 2-dimensional hydraulic models were set up using HEC-RAS 5.0.7 (USACE 2019).

Terrain. The underlying terrain for the site area was provided as a spot elevation in CSV format under file name: "Coordinate _ RL.csv." spot elevation were converted to a 1-metre by 1-metre resolution raster grid digital elevation model in geotif format using Geohecras.

The underlying terrain for the outside area was provided as a SRTM elevation data at a 1-arc-second resolution (approximately 30-metres)

2D Flow Area. A two-dimensional (2D) flow area was delineated across the of project site . A computational mesh spacing of 30 metres was applied to the floodplain areas, with a mesh size of 1 metres by 1 metres applied to the channel areas.

Roughness. A range of Manning’s roughness coefficients was applied to the model as a sensitivity analysis. Channel roughness values ranges from 0.035 to 0.05, and floodplain roughness ranges from 0.05 to 0.08. The higher values were selected for the baseline runs for additional conservatism and to account for shallow flow depths relative to the size of the roughness elements.

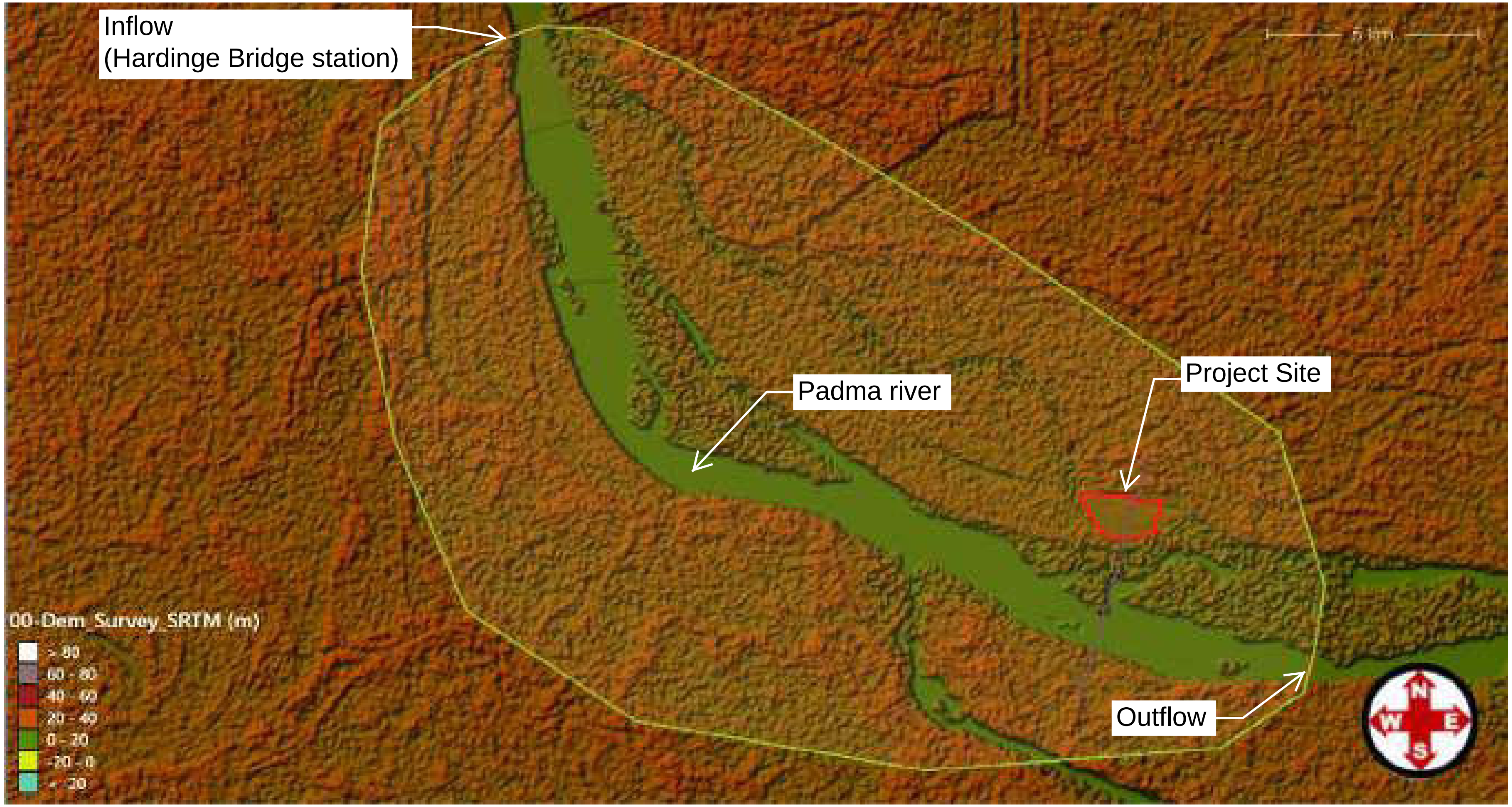
Inflow Boundary Condition. three inflow scenarios were applied as time series flow hydrographs based on available hydrologic analyses:

Q25(pre development stage) = 72,567.81 m3/s.
Q50(pre development stage) = 78,631.09 m3/s.
Q100(pre development stage) = 84,649.60 m3/s.

Outflow Boundary Condition. Normal depth slope :
slope = 0.000035

Computational time step. A variable time step was assigned based on a maximum Currant Number of 2.0. Using this option, HEC-RAS selected the time step based on the assigned computational mesh size and computed velocities. The adopted time step generally ranged between 0.5 and 1.0 seconds. Mass balance errors and water surface elevation convergence errors were checked to ensure model stability and that imbalances remained below reasonable thresholds, confirming compliance with Courant Number criteria.

Simulation window. 6 hrs simulation window was applied in the model runs. Peak discharge rates were converted to unsteady flow hydrographs in the 2D model, with a gradual increase to the peak flow, which is maintained until the maximum inundation extent is reached at all points in the model to simulated an extended, near-steady flow condition.



HEC-RAS 2D model schematic for Pre Development Stage

Annex B-2

Peak Discharge Calculation by Gumbel method

Frequency Analysis of Maximum Annual Discharge of Hardinge Bridge station

Station :	Hardinge Bridge	River:	Ganges-Padma
District :	Pabna	Country :	Bangladesh

Year	Qmax (cu ft/s)	Qmax (m3/s)
1972	1,205,352	34,135.57
1973	1,585,324	44,896.38
1974	966,772	27,378.98
1975	1,752,437	49,629.02
1976	1,814,085	51,374.89
1977	1,734,722	49,127.33
1978	2,027,121	57,408.07
1979	1,288,530	36,491.17
1980	2,050,262	58,063.42
1981	1,899,813	53,802.70
1982	2,129,287	60,301.41
1983	2,042,261	57,836.83
1984	1,992,069	56,415.39
1985	1,691,925	47,915.32
1986	1,799,424	50,959.69
1987	2,685,118	76,042.54
1988	2,484,918	70,372.88
1989	1,116,147	31,609.28
1990	1,761,470	49,884.83
1991	1,944,222	55,060.37
1992	1,474,385	41,754.58
1993	1,579,445	44,729.88
1994	1,615,018	45,737.31
1995	1,718,239	48,660.53
1996	1,924,221	54,493.94
1997	1,409,644	39,921.12
1998	2,581,199	73,099.56
1999	2,158,530	61,129.57
2000	2,130,219	60,327.80
2001	1,886,078	53,413.73
2002	1,447,224	40,985.38
2003	2,114,493	59,882.44
2004	1,331,569	37,710.03
2005	1,540,427	43,624.89
2006	1,315,625	37,258.50
2007	1,914,650	54,222.89
2008	1,785,593	50,567.99
2009	1,363,177	38,605.17
2010	1,422,320	40,280.10
2011	1,719,289	48,690.26
2012	1,563,568	44,280.25
2013	1,914,952	54,231.44
2014	1,533,069	43,416.51
2015	1,648,455	46,684.25
2016	1,982,374	56,140.83
2017	1,731,646	49,040.21
2018	1,429,509	40,483.69
2019	1,992,601	56,430.46
2020	1,600,623	45,329.64
2021	1,991,470	56,398.43

Result of Gumbel Distribution Analysis

No.	Year	Qmax (m3/s)	(Xi-X̄)	(Xi-X̄)^2
1	1972	34135.57	-15589.1807	243022554.7227
2	1973	44896.38	-4828.3737	23313192.1465
3	1974	27378.98	-22345.7663	499333271.2839
4	1975	49629.02	-95.7335	9164.9020
5	1976	51374.89	1650.1379	2722954.9755
6	1977	49127.33	-597.4223	356913.3978
7	1978	57408.07	7683.3174	59033366.0479
8	1979	36491.17	-13233.5797	175127632.5867
9	1980	58063.42	8338.6705	69533425.8010
10	1981	53802.70	4077.9548	16629715.5596
11	1982	60301.41	10576.6585	111865705.1441
12	1983	57836.83	8112.0822	65805877.3859
13	1984	56415.39	6690.6447	44764727.1118
14	1985	47915.32	-1809.4333	3274048.9916
15	1986	50959.69	1234.9383	1525072.7174
16	1987	76042.54	26317.7924	692626198.1570
17	1988	70372.88	20648.1284	426345207.4801
18	1989	31609.28	-18115.4663	328170119.0635
19	1990	49884.83	160.0811	25625.9476
20	1991	55060.37	5335.6177	28468816.3003
21	1992	41754.58	-7970.1661	63523548.2099
22	1993	44729.88	-4994.8669	24948695.6924
23	1994	45737.31	-3987.4396	15899674.3595
24	1995	48660.53	-1064.2209	1132566.0269
25	1996	54493.94	4769.1894	22745167.3957
26	1997	39921.12	-9803.6313	96111185.7722
27	1998	73099.56	23374.8063	546381571.6943
28	1999	61129.57	11404.8203	130069925.2906
29	2000	60327.80	10603.0527	112424727.5260
30	2001	53413.73	3688.9796	13608570.6781
31	2002	40985.38	-8739.3657	76376512.0413
32	2003	59882.44	10157.6924	103178715.4131
33	2004	37710.03	-12014.7153	144353382.6443
34	2005	43624.89	-6099.8567	37208251.6922
35	2006	37258.50	-12466.2493	155407372.4674
36	2007	54222.89	4498.1387	20233251.4550
37	2008	50567.99	843.2444	711061.1613
38	2009	38605.17	-11119.5767	123644985.8626
39	2010	40280.10	-9444.6469	89201355.7155
40	2011	48690.26	-1034.4849	1070158.9140
41	2012	44280.25	-5444.5036	29642619.1717
42	2013	54231.44	4506.6913	20310266.5240
43	2014	43416.51	-6308.2353	39793832.0249
44	2015	46684.25	-3040.5037	9244662.9589
45	2016	56140.83	6416.0823	41166112.6655
46	2017	49040.21	-684.5346	468587.6383
47	2018	40483.69	-9241.0545	85397087.4292
48	2019	56430.46	6705.7110	44966559.8224
49	2020	45329.64	-4395.1060	19316956.5262
50	2021	56398.43	6673.6811	44538018.9653
Sum		2486237.47	0.00	4905028973.46
Average, X̄		49724.7493		
Yn		0.5485		
Sn		1.1607		
Standard Deviation, Sd		10005.1303		

Result of Peak Discharge Calculation using Gumbel Distribution Analysis

No.	X̄	Sn	Yn	Sd	Tr	Yt	K	Qmax(design) m3/s
								XT = X̄ + K(Sd)
1	49724.7493	1.1607	0.5485	10005.1303	2	0.3665	-0.1568	48156.037
2	49724.7493	1.1607	0.5485	10005.1303	5	1.4999	0.8197	57926.077
3	49724.7493	1.1607	0.5485	10005.1303	10	2.2504	1.4662	64394.694
4	49724.7493	1.1607	0.5485	10005.1303	25	3.1985	2.2831	72567.808
5	49724.7493	1.1607	0.5485	10005.1303	50	3.9019	2.8892	78631.091
6	49724.7493	1.1607	0.5485	10005.1303	100	4.6001	3.4907	84649.604

Annex B-3

Flood Modeling by GeoHecRas

Ver: 2.7.0.21426
Feb 6, 2019

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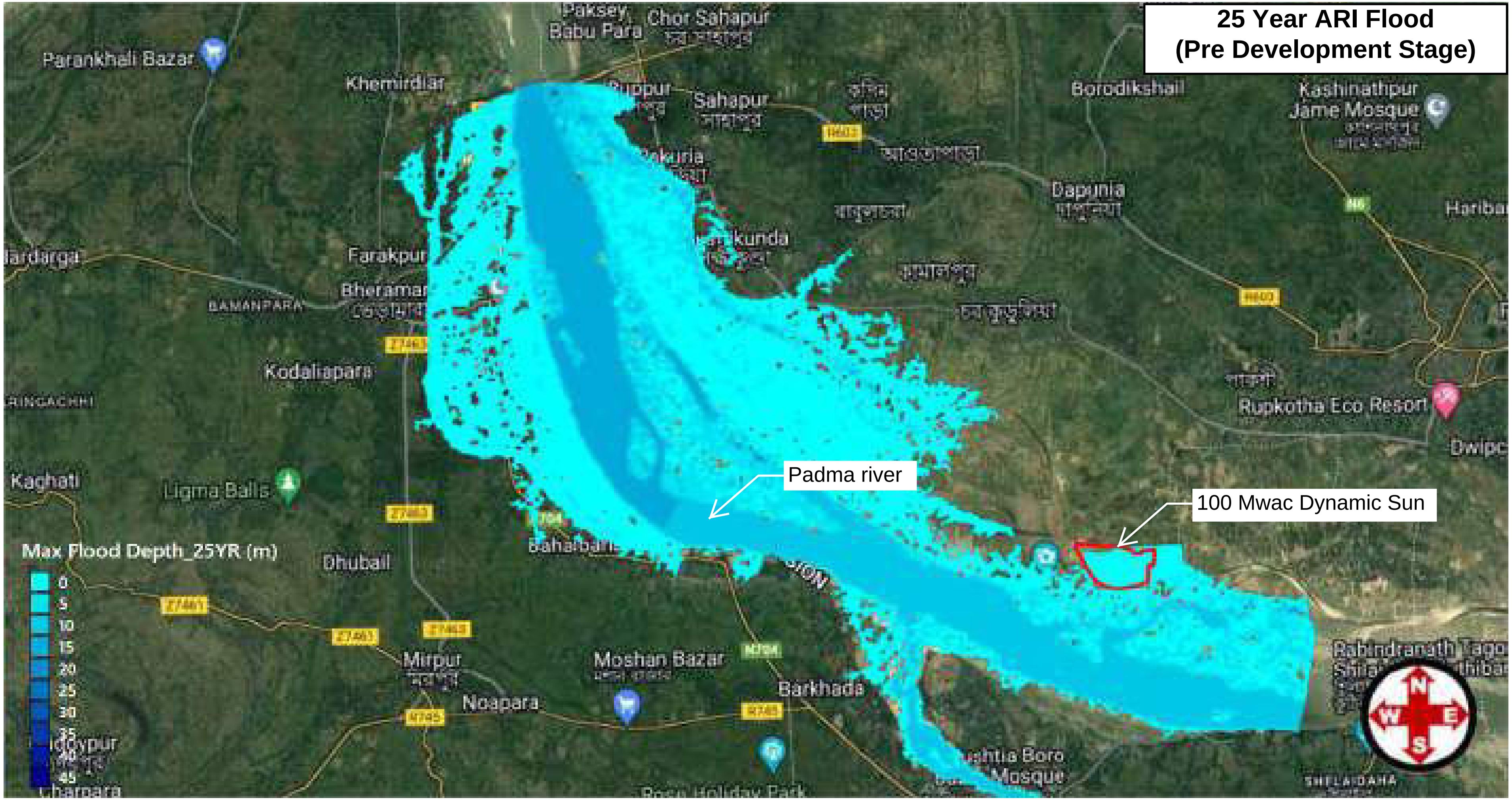
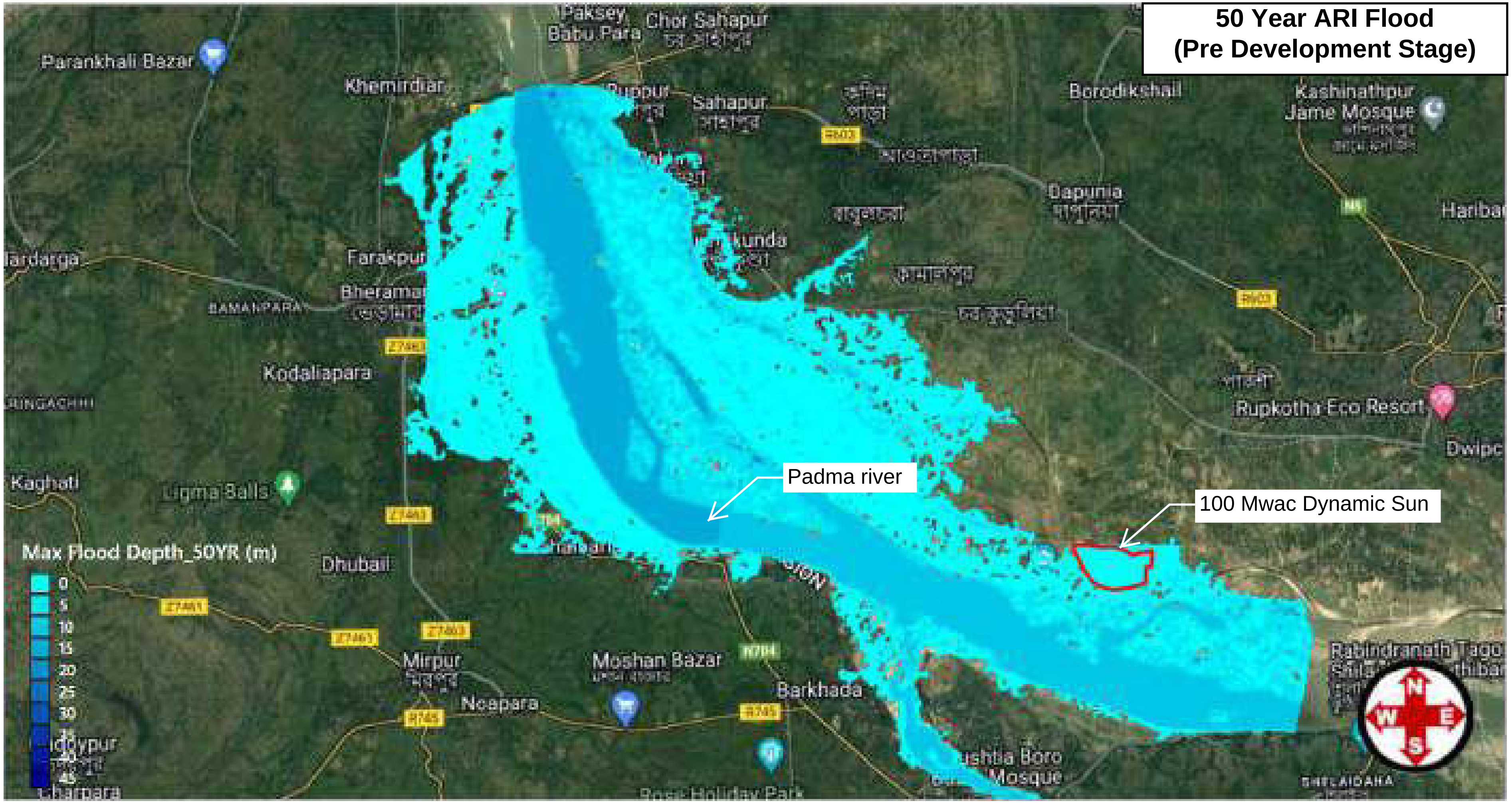

25 Year ARI Flood
(Pre Development Stage)
Padma river
100 Mwac Dynamic Sun
Max Flood Depth_25YR (m)
0
5
10
15
20
25
30
35
40
45
Paksey
Babu Para
Chor Sahapur
Parankhali Bazar
Khemirdiar
Ruppur
Sahapur
Borodikshail
Kashinathpur Jame Mosque
Dapunia
Haribar
Farakpur
Bheramara
BAMANPARA
Kodaliapara
RINGACHHI
Kaghati
Ligma Balls
Dhubail
Baharbari
Rupkotha Eco Resort
Dwipc
Mirpur
Noapara
Moshan Bazar
Barkhada
Rabindranath Tago
Charpara
SHELAIDAHA
N
E
S
W



50 Year ARI Flood
(Pre Development Stage)

Padma river

100 Mwac Dynamic Sun


100 Year ARI Flood
(Pre Development Stage)
Padma river
100 Mwac Dynamic Sun
Max Flood Depth_100YR (m)
0
5
10
15
20
25
30
35
40
45
Paksey
Babu Para
Chor Sahapur
Parankhali Bazar
Khemirdiar
Sahapur
Borodikshail
Kashinathpur Jame Mosque
Dapunia
Hariba
Kunda
Farakpur
Bheramara
BAMANPARA
Kodaliapara
RINGACHHI
Rupkotha Eco Resort
Dwipo
Kaghati
Ligma Balls
Dhubail
Mirpur
Moshan Bazar
Noapara
Barkhada
Charpara
Rabindranath Tago
SHELAIDAHA
N
W
E
S

Annex C

Hydraulic Modeling
25, 50, 100 Year ARI from Local Catchment

(Post Development Stage)

Annex C-1

Hydraulic Modeling set up from Local Catchment

1. MODEL SET UP

To assess the flood risk for this Solar Plant site under proposed conditions 2-dimensional hydraulic models were set up using HEC-RAS 5.0.7 (USACE 2019).

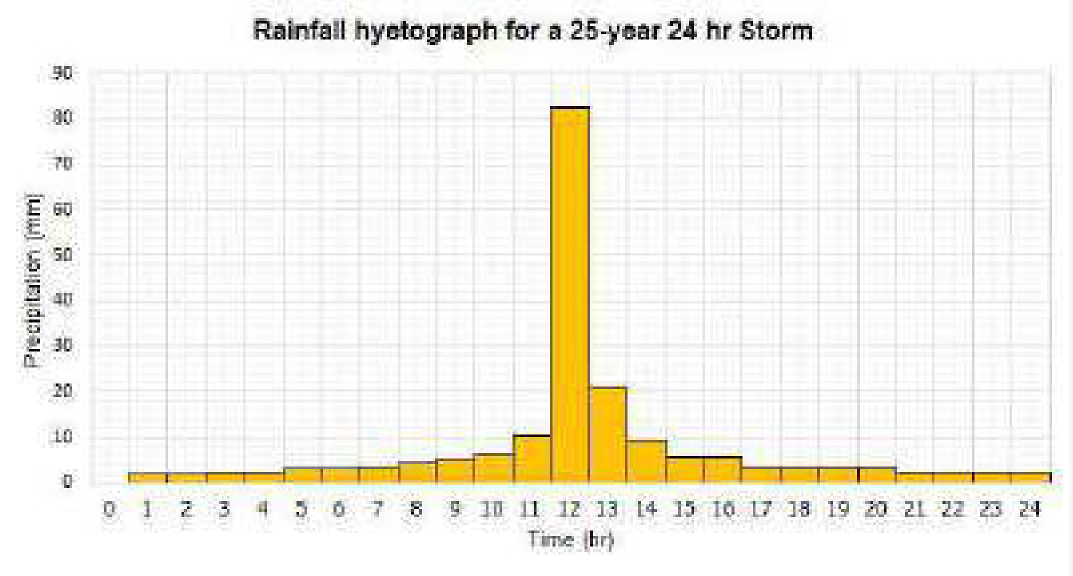
Terrain. The underlying terrain for the site area was provided as a spot elevation in CSV format under file name: "Coordinate _ RL.csv." spot elevation were converted to a 1-metre by 1-metre resolution raster grid digital elevation model in geotif format using Geohecras.

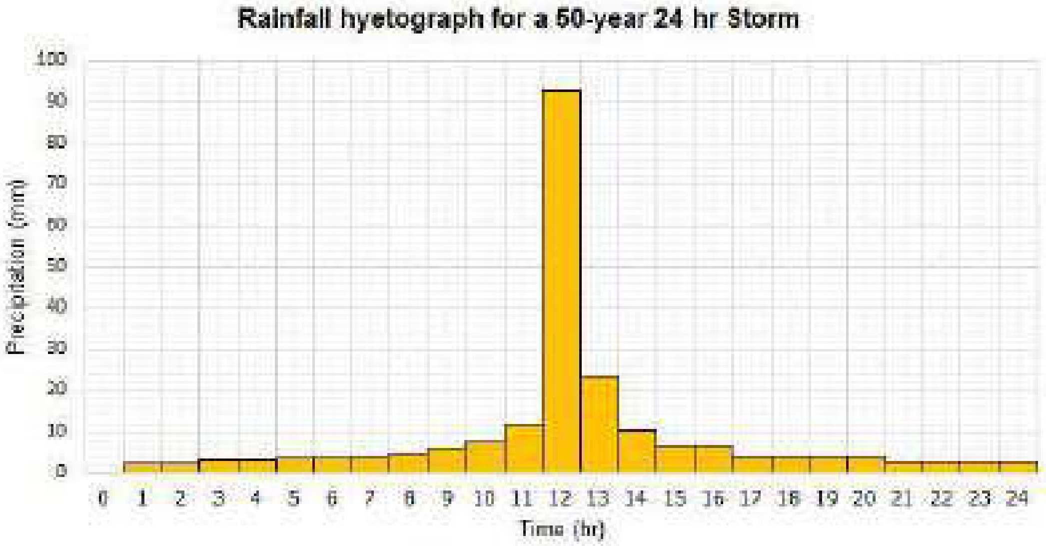
2D Flow Area. A two-dimensional (2D) flow area was delineated across the of project site . A computational mesh spacing of 1 metres was applied to the floodplain areas

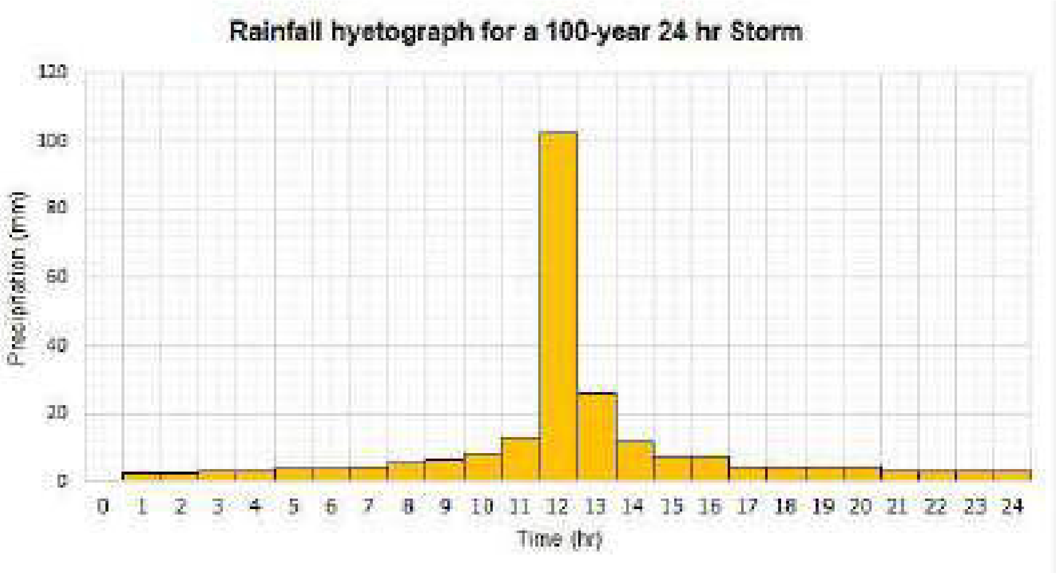
Roughness. A range of Manning's roughness coefficients was applied to the model as a sensitivity analysis. Channel roughness values ranges from 0.035 to 0.05, and floodplain roughness ranges from 0.05 to 0.08. The higher values were selected for the baseline runs for additional conservatism and to account for shallow flow depths relative to the size of the roughness elements.

Precipitation Boundary Condition.

Boundary Condition: Precipitation Hydrograph



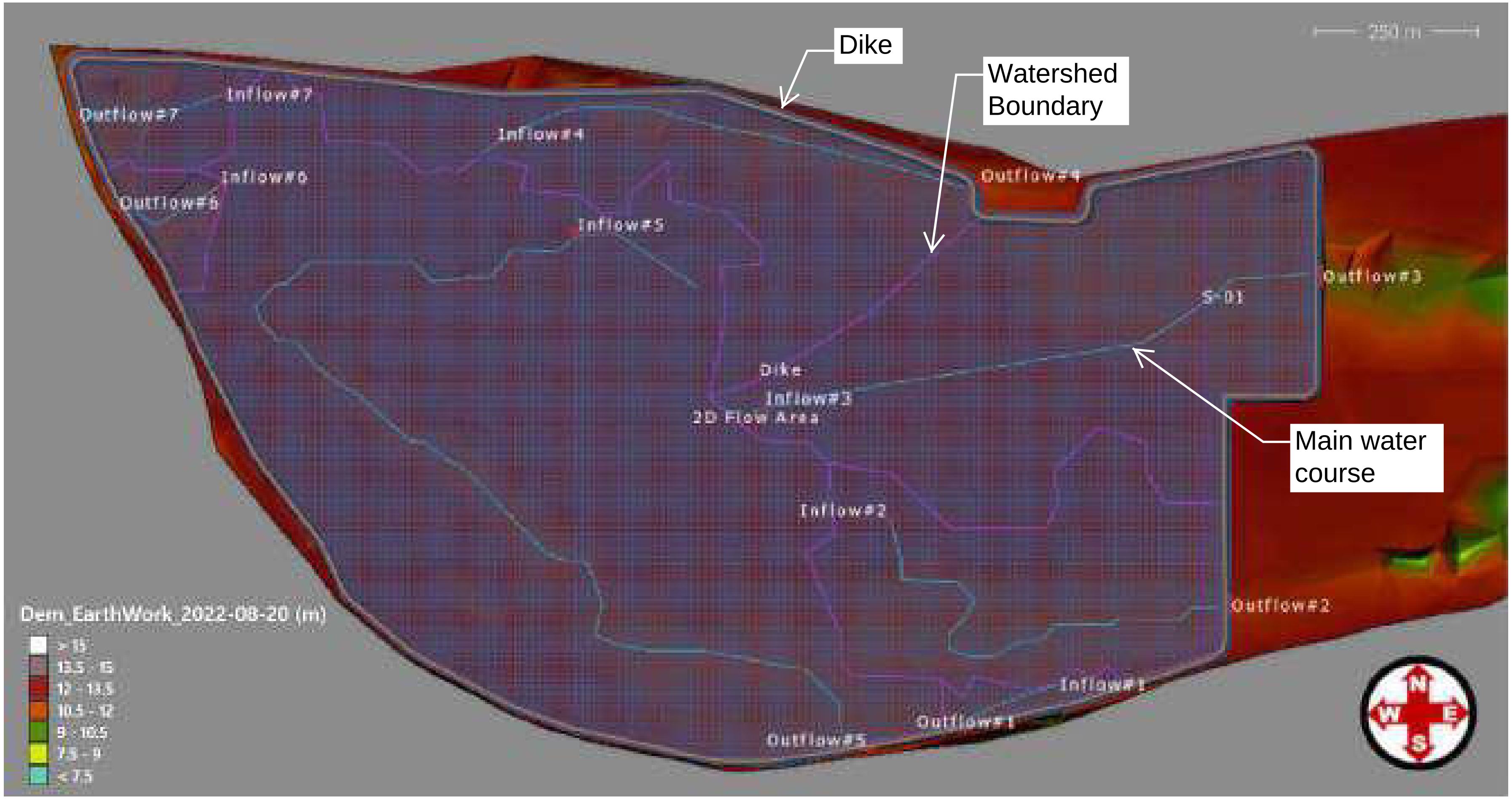




Outflow Boundary Condition. Normal depth slope :
Slope(Outflow#1) = 0.020095
Slope(Outflow#2) = 0.004989
Slope(Outflow#3) = 0.009909
Slope(Outflow#4) = 0.016861
Slope(Outflow#5) = 0.005715
Slope(Outflow#6) = 0.027521
Slope(Outflow#7) = 0.004271

Computational time step. A variable time step was assigned based on a maximum Currant Number of 2.0. Using this option, HEC-RAS selected the time step based on the assigned computational mesh size and computed velocities. The adopted time step generally ranged between 0.5 and 1.0 seconds. Mass balance errors and water surface elevation convergence errors were checked to ensure model stability and that imbalances remained below reasonable thresholds, confirming compliance with Courant Number criteria.

Simulation window. 24 hrs simulation window was applied in the model runs.



HEC-RAS 2D model schematic for Post Development Stage

Annex C-2

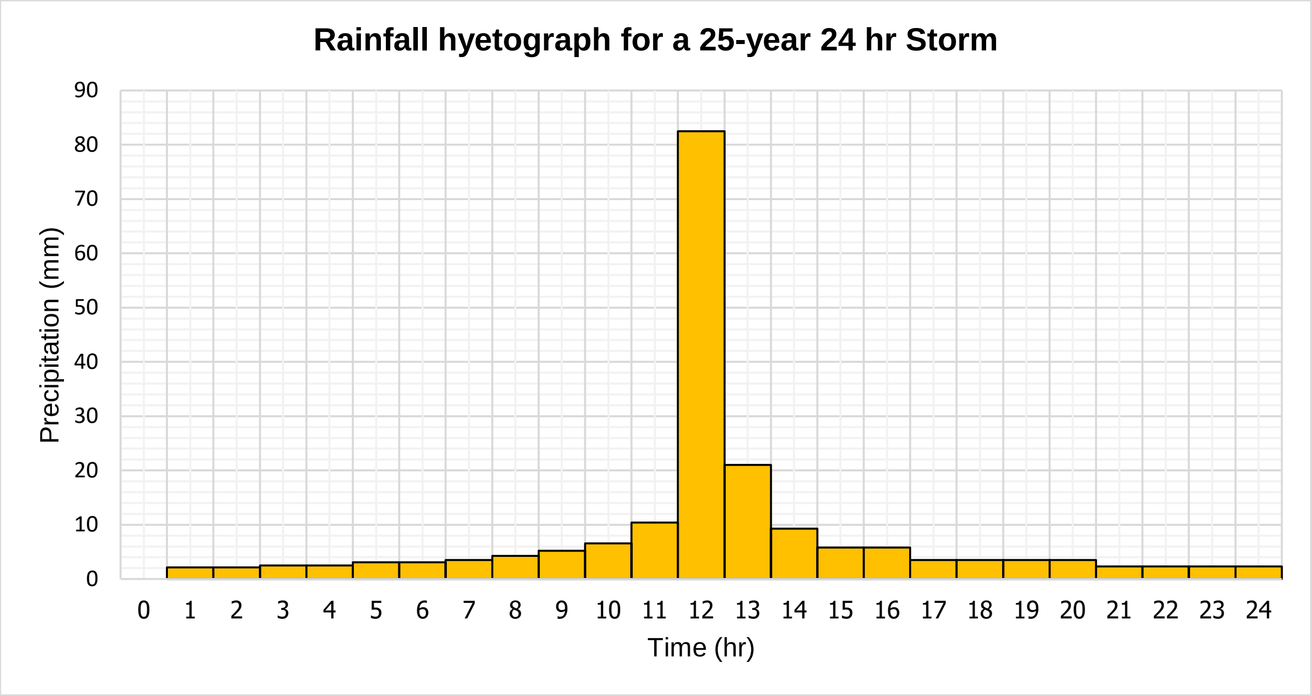
Design Precipitation Hyetographs by SCS method

Design Precipitation Hyetographs by SCS method

SCS rainfall type curves = Type II

P(24hr)
at 25 Year ARI = 192.7309 mm
Time increment 1 hr

Time	Cumulative Fraction	Cumulative Precipitation	Incremental Precipitation
hr	Pt/P24	Pt (mm)	(mm)
0	0.000	0.00	0
1	0.011	2.12	2.12
2	0.022	4.24	2.12
3	0.035	6.75	2.51
4	0.048	9.25	2.51
5	0.064	12.33	3.08
6	0.080	15.42	3.08
7	0.098	18.89	3.47
8	0.120	23.13	4.24
9	0.147	28.33	5.20
10	0.181	34.88	6.55
11	0.235	45.29	10.41
12	0.663	127.78	82.49
13	0.772	148.79	21.01
14	0.820	158.04	9.25
15	0.850	163.82	5.78
16	0.880	169.60	5.78
17	0.898	173.07	3.47
18	0.916	176.54	3.47
19	0.934	180.01	3.47
20	0.952	183.48	3.47
21	0.964	185.79	2.31
22	0.976	188.11	2.31
23	0.988	190.42	2.31
24	1.000	192.73	2.31

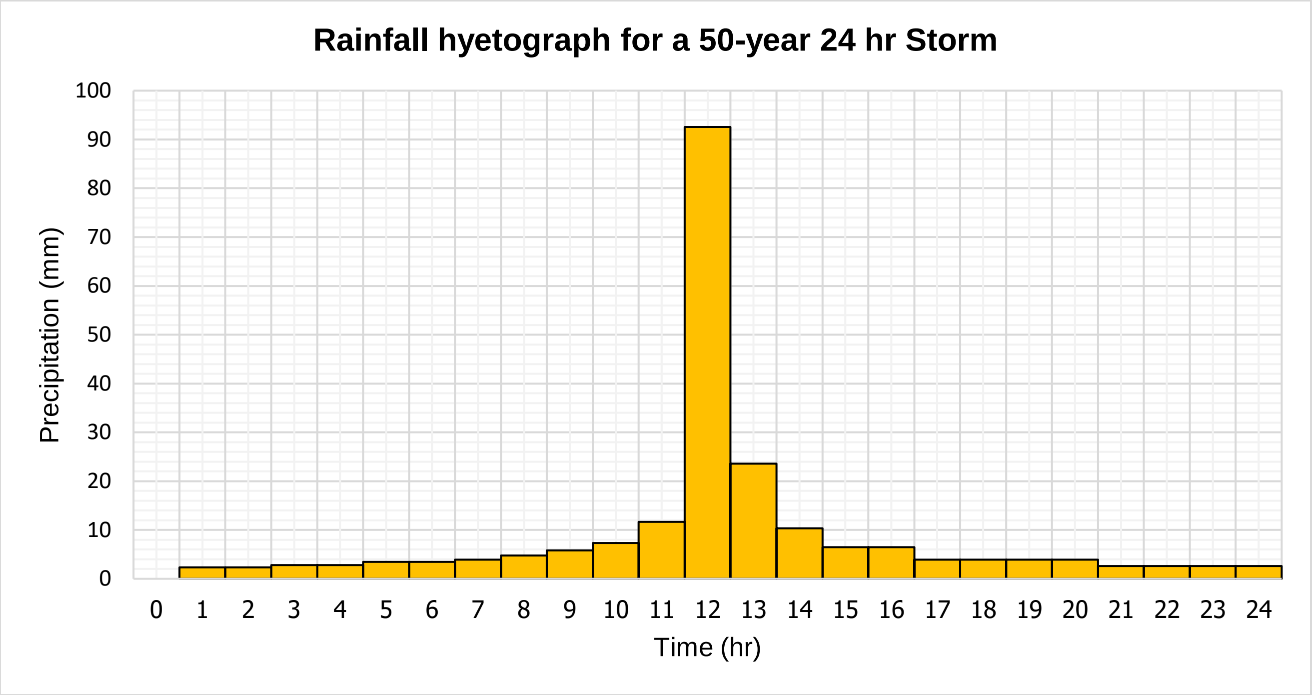

Rainfall hyetograph for a 25-year 24 hr Storm
Precipitation (mm)
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Time (hr)

Design Precipitation Hyetographs by SCS method

SCS rainfall type curves = Type II

P(24hr)
at 50 Year ARI = 216.1982 mm
Time increment 1 hr

Time	Cumulative Fraction	Cumulative Precipitation	Incremental Precipitation
hr	Pt/P24	Pt (mm)	(mm)
0	0.000	0.00	0
1	0.011	2.38	2.38
2	0.022	4.76	2.38
3	0.035	7.57	2.81
4	0.048	10.38	2.81
5	0.064	13.84	3.46
6	0.080	17.30	3.46
7	0.098	21.19	3.89
8	0.120	25.94	4.76
9	0.147	31.78	5.84
10	0.181	39.13	7.35
11	0.235	50.81	11.67
12	0.663	143.34	92.53
13	0.772	166.91	23.57
14	0.820	177.28	10.38
15	0.850	183.77	6.49
16	0.880	190.25	6.49
17	0.898	194.15	3.89
18	0.916	198.04	3.89
19	0.934	201.93	3.89
20	0.952	205.82	3.89
21	0.964	208.42	2.59
22	0.976	211.01	2.59
23	0.988	213.60	2.59
24	1.000	216.20	2.59



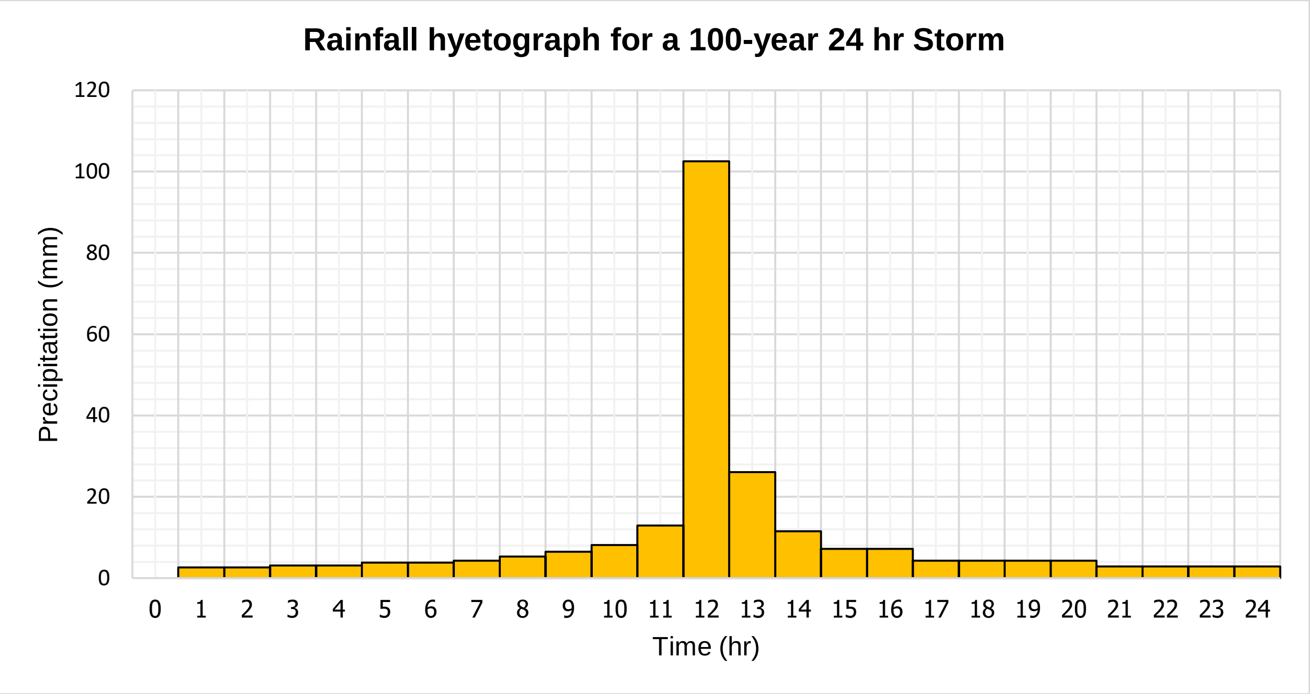
Rainfall hyetograph for a 50-year 24 hr Storm

Design Precipitation Hyetographs by SCS method

SCS rainfall type curves = Type II

P(24hr)
at 100 Year ARI = 239.4923 mm
Time increment 1 hr

Time	Cumulative Fraction	Cumulative Precipitation	Incremental Precipitation
hr	Pt/P24	Pt (mm)	(mm)
0	0.000	0.00	0
1	0.011	2.63	2.63
2	0.022	5.27	2.63
3	0.035	8.38	3.11
4	0.048	11.50	3.11
5	0.064	15.33	3.83
6	0.080	19.16	3.83
7	0.098	23.47	4.31
8	0.120	28.74	5.27
9	0.147	35.21	6.47
10	0.181	43.35	8.14
11	0.235	56.28	12.93
12	0.663	158.78	102.50
13	0.772	184.89	26.10
14	0.820	196.38	11.50
15	0.850	203.57	7.18
16	0.880	210.75	7.18
17	0.898	215.06	4.31
18	0.916	219.37	4.31
19	0.934	223.69	4.31
20	0.952	228.00	4.31
21	0.964	230.87	2.87
22	0.976	233.74	2.87
23	0.988	236.62	2.87
24	1.000	239.49	2.87


Rainfall hyetograph for a 100-year 24 hr Storm
Precipitation (mm)
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Time (hr)

Annex C-3

Flood Modeling by GeoHecRas

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Feb 6, 2019

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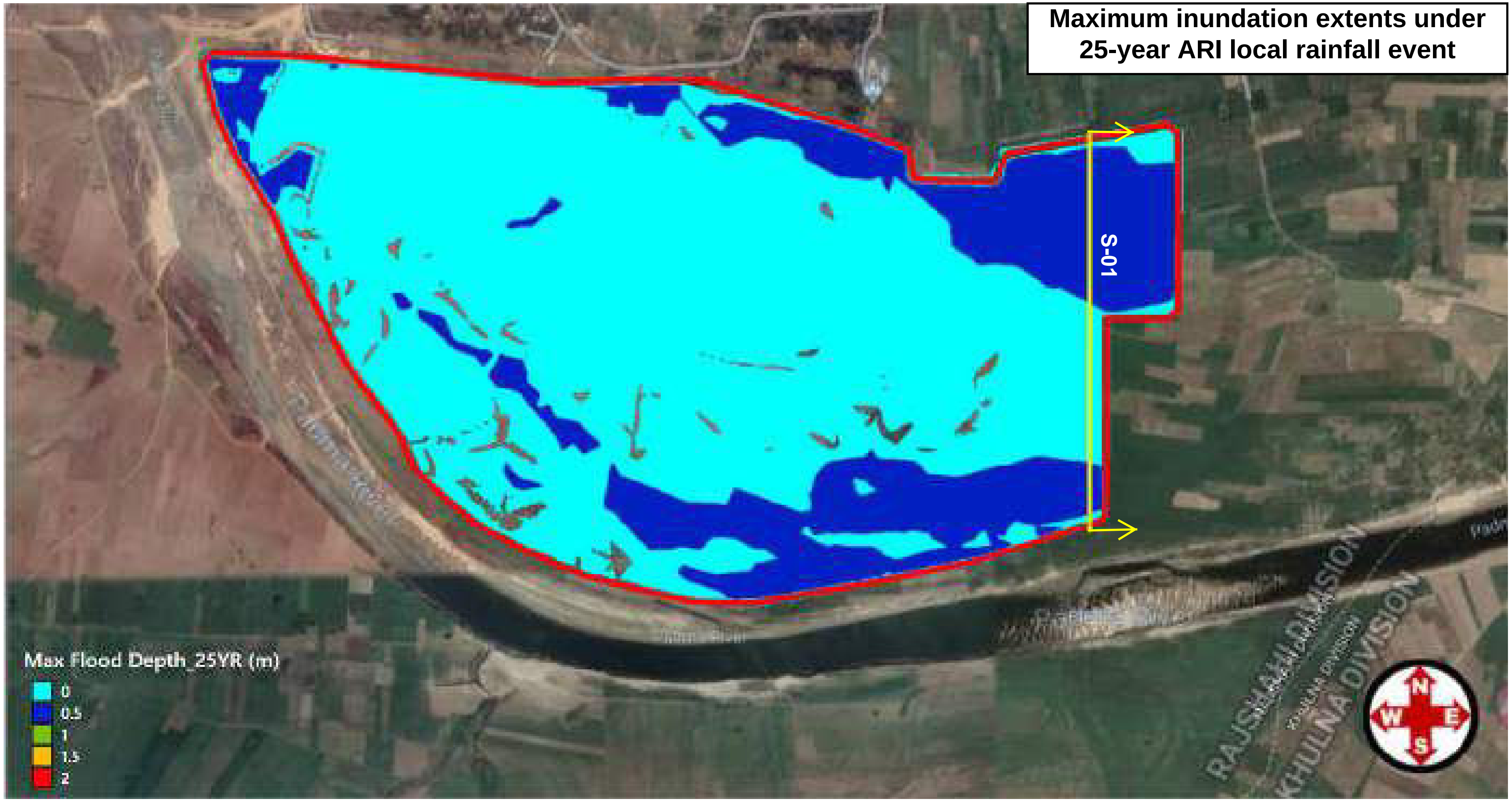
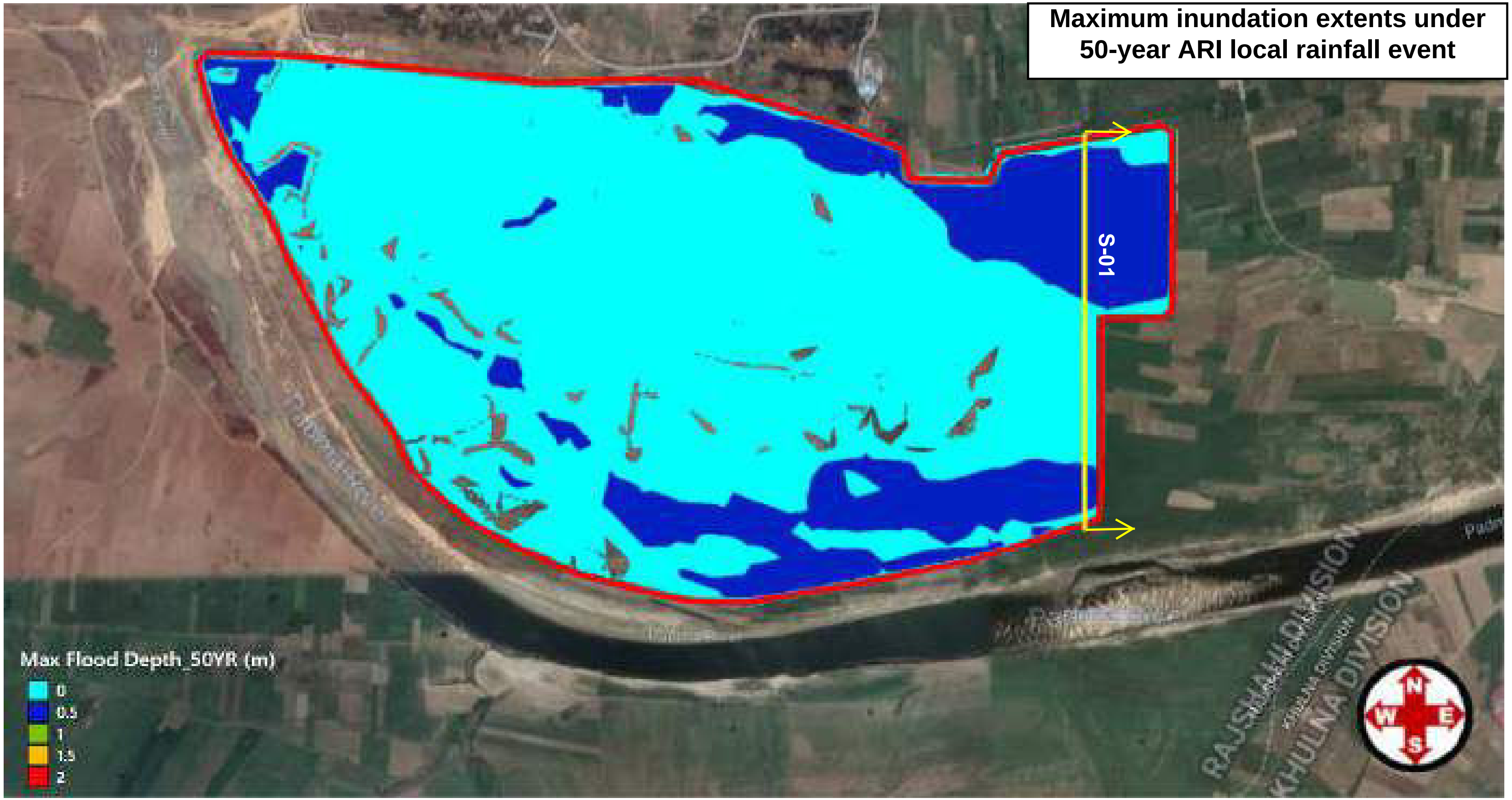
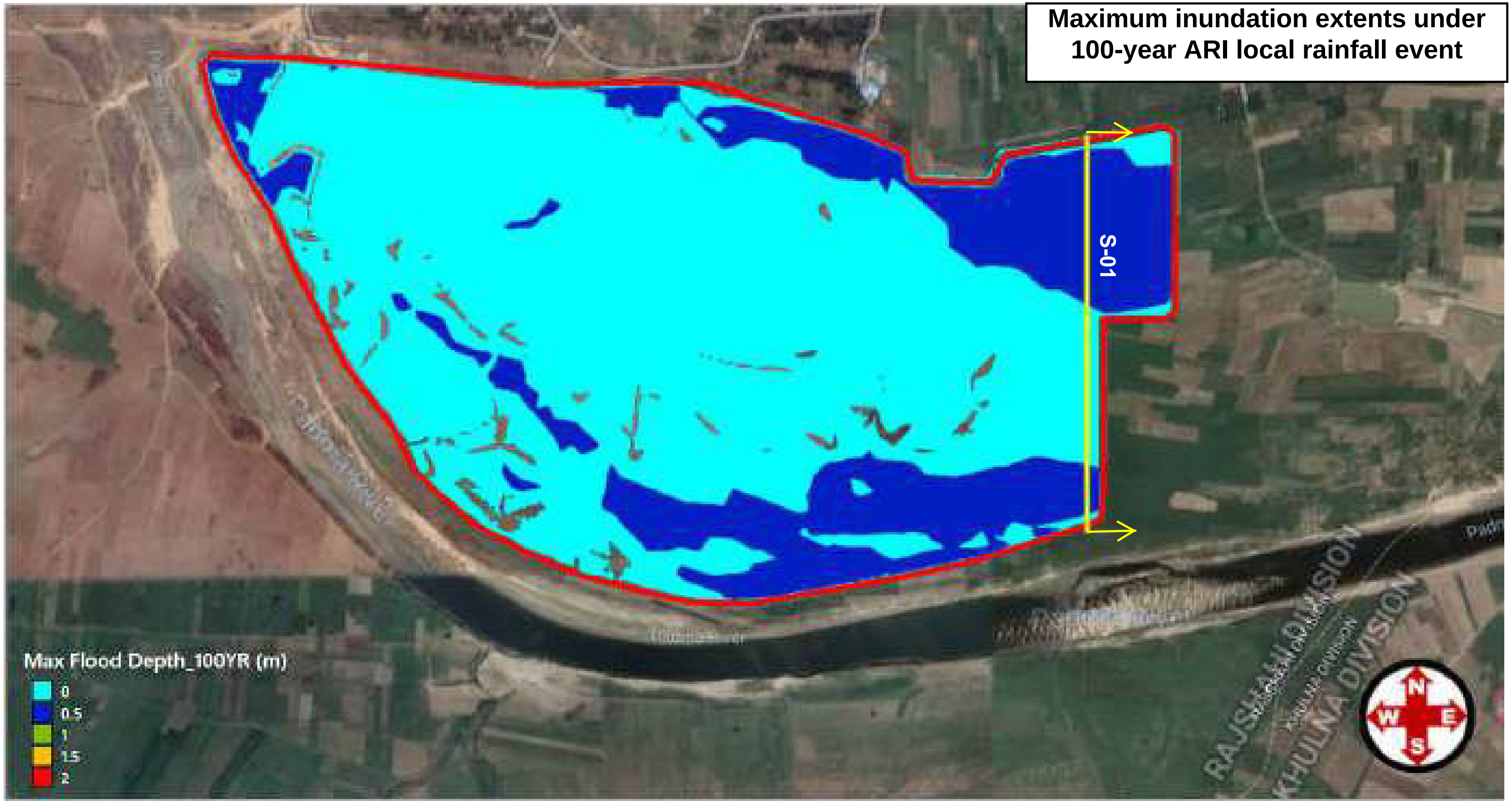


Maximum inundation extents under 25-year ARI local rainfall event

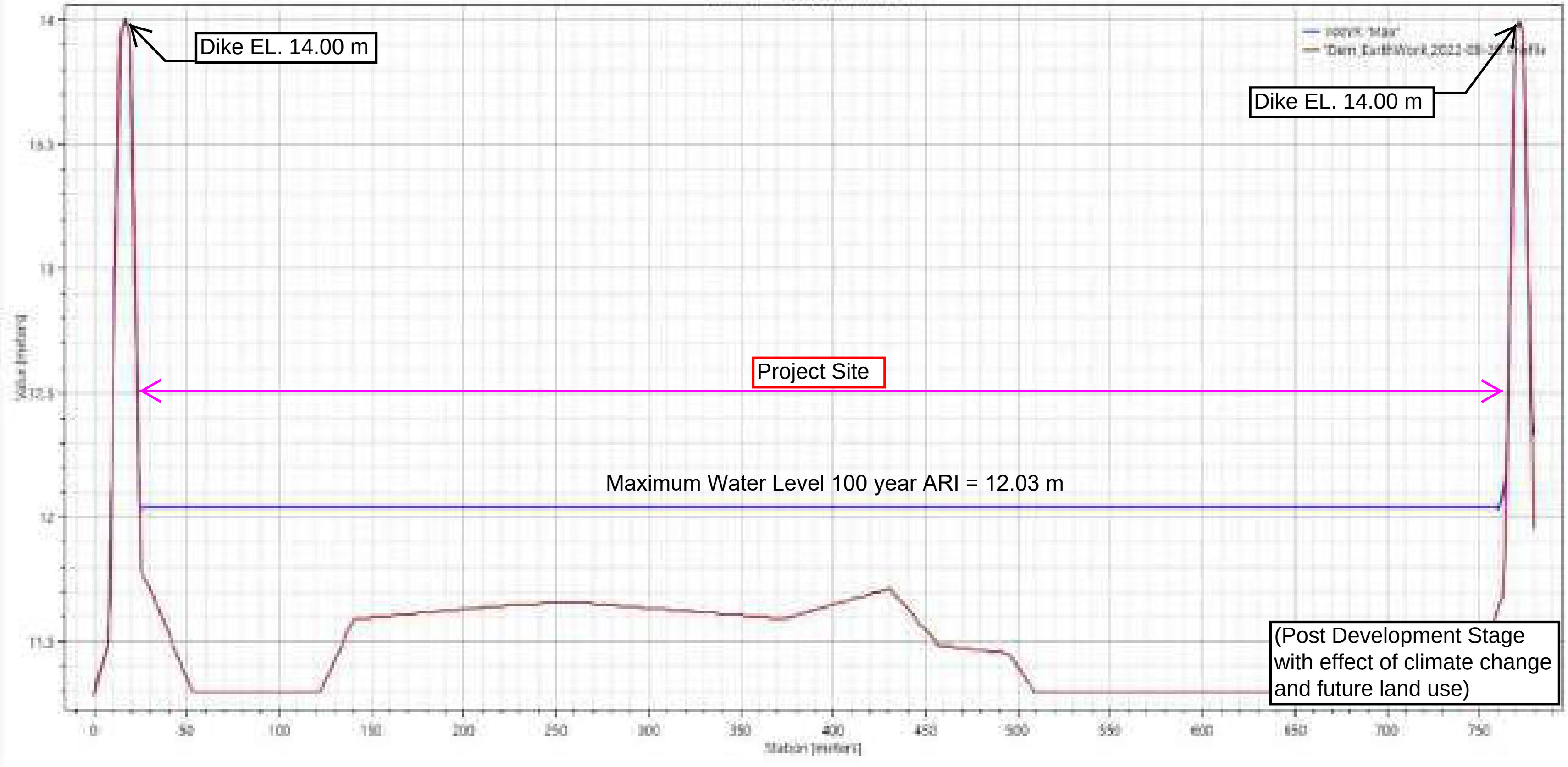


Maximum inundation extents under 50-year ARI local rainfall event



Maximum inundation extents under 100-year ARI local rainfall event

Water Surface Elevation on 'S-01'



Annex D

The Flow Rate at The Project Site from Local Rain

Annex D-1

Double Mass Curve Analysis of Rainfall Data

Station: 1
Station: 2
Station: 3

Rainfall data 15 years back records
from (https://openweathermap.org/)

Map of Rainfall Stations

Rainfall Station

Rainfall Station No.	Lat	Long	Upazila	District
1	24.016449	89.262932	Pabna Sadar	Pabna
2	23.839301	89.151114	Kushtia Sadar	Kushtia
3	24.065274	89.030285	Ishwardi	Pabna

Summary of Rainfall Data From

Station: 1
Station: 2
Station: 3

Table D1-1 : Maximum Daily Rainfall Data

Station :	1	Lat :	24.016449
Duration :	2007-2021	Long:	89.262932

Year	Maximum Daily Rainfall
	mm
2007	126.90
2008	93.18
2009	96.63
2010	74.60
2011	121.09
2012	40.05
2013	61.23
2014	135.03
2015	176.40
2016	74.75
2017	78.28
2018	62.57
2019	43.90
2020	108.72
2021	74.82

Table D1-2 : Maximum Daily Rainfall Data

Station :	2	Lat :	23.839301
Duration :	2007-2021	Long:	89.151114

Year	Maximum Daily Rainfall
	mm
2007	111.16
2008	96.59
2009	69.53
2010	52.43
2011	163.83
2012	51.61
2013	37.67
2014	74.95
2015	154.83
2016	52.98
2017	78.30
2018	53.22
2019	65.11
2020	113.46
2021	80.69

Table D1-3 : Maximum Daily Rainfall Data

Station :	3	Lat :	24.065274
Duration :	2007-2021	Long:	89.030285

Year	Maximum Daily Rainfall
	mm
2007	104.89
2008	88.51
2009	64.58
2010	58.22
2011	152.25
2012	87.99
2013	42.86
2014	118.04
2015	189.62
2016	71.87
2017	64.68
2018	63.01
2019	116.16
2020	71.66
2021	76.44

Double Mass Curve Analysis for Consistency Checking of Rainfall Data

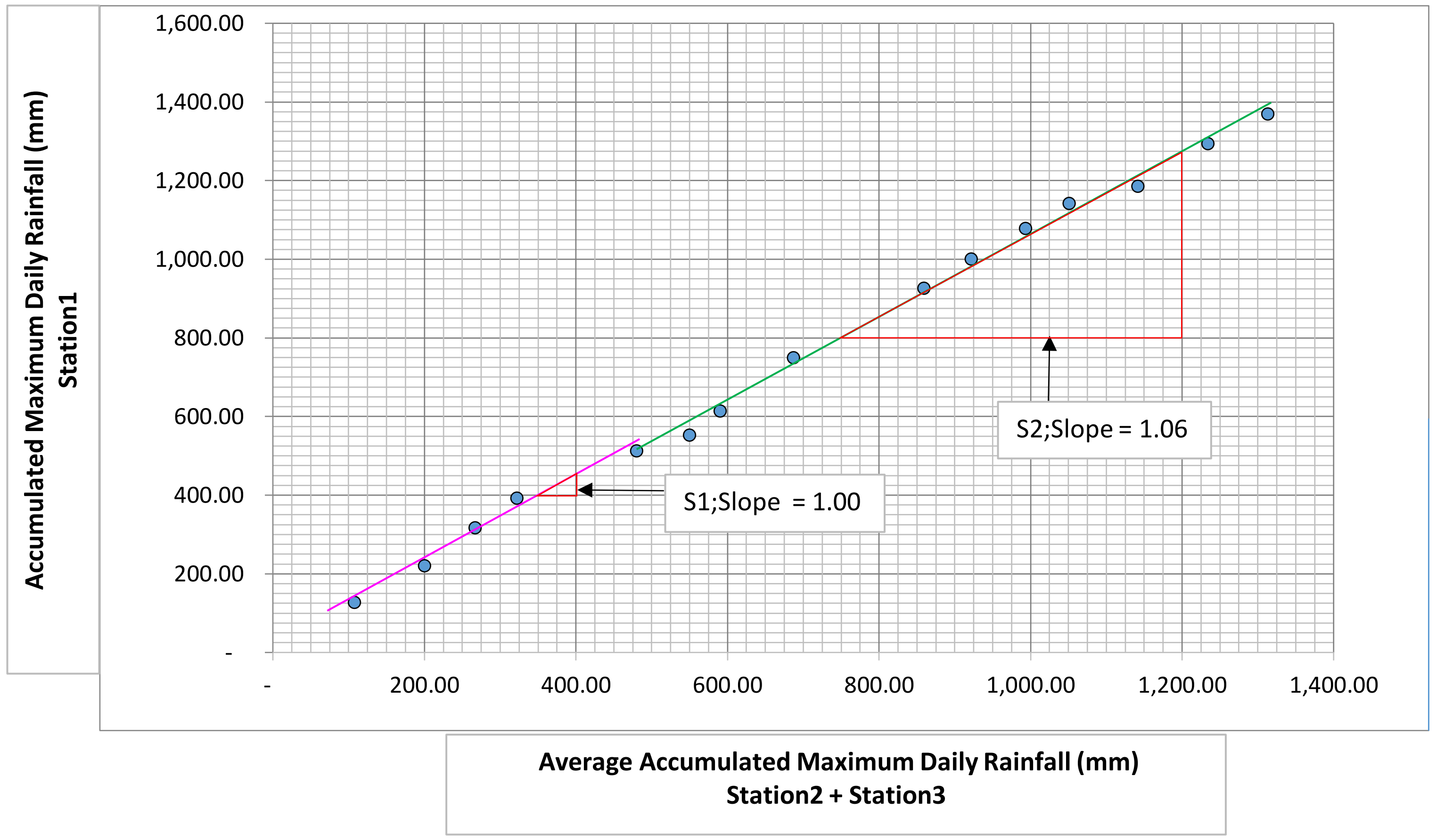
Station: 1

Table D1-4: Maximum Daily Rainfall Data (2007 - 2021) for Double Mass Curve Analysis

Stations : Station1 - Station2 - Station3

Year	Station1		Station2	Station3	Avg Maximum Daily Rainfall	Avg Acc Maximum Daily Rainfall
	Maximum Daily Rainfall	Acc Maximum Daily Rainfall	Maximum Daily Rainfall	Maximum Daily Rainfall	Total_Station2 + Station3	Total_Station2 + Station3
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
2007	126.90	126.90	111.16	104.89	108.03	108.03
2008	93.18	220.08	96.59	88.51	92.55	200.58
2009	96.63	316.71	69.53	64.58	67.06	267.63
2010	74.60	391.31	52.43	58.22	55.33	322.96
2011	121.09	512.40	163.83	152.25	158.04	481.00
2012	40.05	552.45	51.61	87.99	69.80	550.80
2013	61.23	613.68	37.67	42.86	40.27	591.06
2014	135.03	748.71	74.95	118.04	96.50	687.56
2015	176.40	925.11	154.83	189.62	172.23	859.78
2016	74.75	999.86	52.98	71.87	62.43	922.21
2017	78.28	1,078.14	78.30	64.68	71.49	993.70
2018	62.57	1,140.71	53.22	63.01	58.12	1,051.81
2019	43.90	1,184.61	65.11	116.16	90.64	1,142.45
2020	108.72	1,293.33	113.46	71.66	92.56	1,235.01
2021	74.82	1,368.15	80.69	76.44	78.57	1,313.57

Y	X
Acc Maximum Daily Rainfall	Avg Acc Maximum Daily Rainfall
Station1	Station2 + Station3
(mm)	(mm)
126.90	108.03
220.08	200.58
316.71	267.63
391.31	322.96
512.40	481.00
552.45	550.80
613.68	591.06
748.71	687.56
925.11	859.78
999.86	922.21
1,078.14	993.70
1,140.71	1,051.81
1,184.61	1,142.45
1,293.33	1,235.01
1,368.15	1,313.57



ID	y2	y1	x2	x1	Slope
S1	450.00	400.00	400.00	350.00	1.00
S2	1,275.00	800.00	1,200.00	750.00	1.06

% Diff Slope [(S2-S1)/S2]*100%

5.26 %

Double Mass Curve Analysis of Maximum Daily Rainfall
Year : 2007 - 2021
Stations : Station1 - Station2 - Station3

Summary of Analysis

Rainfall data from these 3 stations were further tested for consistency by Double Mass Curve Method. From the plotted double mass curve, the maximum different of the slope between any 2 portions on the curve is equal to 5.26% which is less than 10%, therefore, from this comparison with 2 other nearby stations, it can be concluded that rainfall data from station 1 is on the level of acceptable consistency.

Back ground Theory of Homogeinty and Double Mass Curve Analysis

Homogeneity tests on daily rainfall series

Statistical Methods

Four homogeneity tests are used to test the homogeneity of the rainfall data. Standard normal homogeneity test (SNHT), Buishand range (BR) test, Pettitt test, and von Neumann ratio (VNR) test are selected. Under null hypothesis, the annual values Y_i of the testing variables Y are independent and identically distributed and the series are considered as homogeneous. Meanwhile under alternative hypothesis, SNHT, BR test and Pettitt test assume the series consisted of break in the mean and considered as inhomogeneous. These three tests are capable to detect the year where break occurs. Meanwhile VNR test is not able to give information on the year break because the test assumes the series is not randomly distributed under alternative hypothesis.

There are some differences between SNHT, BR test and Pettitt test. SNHT is sensitive in detecting the breaks near the beginning and the end of the series. BR test and Pettitt test are easier to identify the break in the middle of the series. Besides, the SNHT and BR test assumed Y_i is normally distributed, whereas Pettitt test does not need this assumption because it is a non-parametric rank test.

1. Standard Normal Homogeneity Test

A statistic $T(y)$ is used to compare the mean of the first y years with the last of $(n-y)$ years and can be written as below:

$$T_y = y\overline{z_1} + (n-y)\overline{z_2}, \; y = 1,2,....,n \tag{1}$$

where

$$\overline{z_1} = \frac{1}{y}\sum_{i=1}^{n}\frac{(Y_i - \overline{Y})}{s} \quad \text{and} \quad \overline{z_2} = \frac{1}{n-y}\sum_{i=y+1}^{n}\frac{(Y_i - \overline{Y})}{s} \tag{2}$$

The year y consisted of break if value of T is maximum. To reject null hypothesis, the test statistic,

$$T_0 = \max_{1 \le y \le n} T_y \tag{3}$$

is greater than the critical value, which depends on the sample size.

2. Buishand Range Test

The adjusted partial sum is defined as:

$$S_0^* = 0 \text{ and } S_y^* = \sum_{i=1}^{y}(Y_i - \overline{Y}), \; \text{y} = 1,2,...,n \tag{4}$$

When the series is homogeneous, then the value of S_y^* will rise and fall around zero. The year y has break when S_y^* has reached a maximum (negative shift) or minimum (positive shift). Rescaled adjusted range, R is obtained by

$$R = \frac{(\max_{0 \le y \le n} S_y^* - \min_{0 \le y \le n} S_y^*)}{s} \qquad (5)$$

The $R/\sqrt{n}$ is then compared with the critical values given by Buishand (1982).

3. Pettitt Test

This test is based on the rank, r_i of the Y_i and ignores the normality of the series.

$$X_y = 2\sum_{i=1}^{y} r_i - y(n+1), \quad y = 1,2,...,n \qquad (6)$$

The break occurs in year k when

$$X_k = \max_{1 \le y \le n} |X_y| \qquad (7)$$

The value is then compared with the critical value by Pettitt (1979).

4. Von Neumann Ratio Test

It is a test that used the ratio of mean square successive (year to year) difference to the variance. The test statistic is shown as follows:

$$N = \frac{\sum_{i=1}^{n-1} (Y_i - Y_{i+1})^2}{\sum_{i=1}^{n} (Y_i - \overline{Y})^2} \qquad (8)$$

THEORETICAL BASIS OF THE DMC

The DMC is a widely used approach to investigate the consistency and long-term trend of hydro-meteorological time series (Mu, Zhang, Gao et al., 2010). The method was first employed to analyse the consistency of precipitation records in order to correct the measurements,

The principle of the DMC, as stated in Searcy and Hardison (1960), is that the cumulative values of one variable increase linearly with those of another if the ratio of the studied variables is a constant. In the DMC, the cumulative values of relevant variables are plotted with the x- and y- coordinates. If values of x and y axes are equally affected by external disturbances, then a DMC is a straight line; however, slope breaks are common in the DMC and present additional information on the relationship between the studied variables (Kalra & Kumar, 1989; Searcy & Hardison, 1960; Wigbout, 1973). The breaks can be driven by various factors, which impact the collection of sediment or run-off discharge such as changes in sediment or run-off flow, urbanization, revegetation or deforestation, and soil and water conservation measures and climate change. Most importantly, slope breaks are able to help determine the time for the occurrence of a change in the DMC (i.e., change-point year) (Searcy & Hardison, 1960). Generally, a slope break can be ignored if it lasts no more than 5 years, otherwise, it should be treated as a trend and further studied (Searcy & Hardison, 1960). Once the change-point year has been determined, records for the relevant variables would be checked to determine whether there were any anthropogenic disturbances before the change-point year. It can be concluded that slope changes are driven by natural causes if there were no anthropogenic disturbances; otherwise, the changes may result from human activities, and a further study can be undertaken to quantitatively assess the impact of natural causes and human activities for the period after the change-point year. In hydrological studies, the DMC is often used to quantify the relative impact of climate (i.e., precipitation) and human activities (i.e., land use) on the change of total streamflow and sediment discharge for the period after the transition years (Gao, Geissen, Ritsema, Mu, & Wang, 2013). Such work is useful for policy makers to optimize land use patterns and improve the sustainability of eco-environment.

DERIVATION OF THE DMC

The derivation of the DMC for hydrological benefit evaluations includes four steps, which are the establishment of a plot between cumulative annual precipitation and streamflow or sediment discharge, detection of changing points in the DMC, estimation of the total variation of run-off (ΔR_c) and sediment flow (ΔS_c) over the time after the change-point year, and determination of the relative effect of precipitation and anthropogenic disturbances. They are detailed in the following paragraphs, in which T_i represents a time series whereas P_i, R_i, and S_i stand for precipitation, run-off, and sediment discharge at *i* year, respectively. It should be noted that in the DMC, other precipitation-related factors (e.g., rainfall intensity of flood seasons) can also be used to develop relationships with streamflow or sediment discharge. Here, we used annual precipitation as an example.

Step 1. Establishing the DMC.

This step includes the calculation of cumulative precipitation (ΣP), run-off (ΣR) and sediment discharge (ΣS), and plotting of ΣP versus ΣR (or ΣP versus ΣS). In general, vertical axis is the tested variable (i.e., ΣR or ΣS) whereas horizontal axis is the reference variable (i.e. ΣP; Figure 1).

$$\sum P = \sum_{i=1}^{n} P_i \tag{1}$$

$$\sum R = \sum_{i=1}^{n} R_i \tag{2}$$

$$\sum S = \sum_{i=1}^{n} S_i \tag{3}$$

Step 2. Detecting changing points of the DMC

Actually identification of changing points is to find the turning points of the DMC slope (k) (i.e., slope breaks). For the DMC shown in Figure 1, the slope (k) can be expressed as

$$k_{i+1} = \tan\theta = \frac{\Delta R}{\Delta P} = \frac{\sum R_{i+1} - \sum R_i}{\sum P_{i+1} - \sum P_i}. \tag{4}$$

In order to avoid the shortfalls of previous methods (i.e., empirical methods and the direct use of changing points in streamflow or sediment discharge), a nonparametric method proposed by Pettitt (1979) was employed to identify changing points of the DMC slope (k). This method determines a significant change in the mean of a time series when the occurrence of them is unassured. The test utilizes the Mann–Whitney statistic $U_{t,N}$ that examines if two sample sets (x_1, ... x_t and x_{t+1}, ... x_N) come out of the same population. The test statistic $U_{t,N}$ is defined as

$$U_{t,N} = U_{t-1,N} + \sum_{j=1}^{N} \operatorname{sgn}(X_t - X_j) \quad \text{for} \quad t = 2, \ \ldots, \ N \tag{5}$$

and

$$\begin{array}{ll} \text{if}\,(X_t - X_j) > 0, & \operatorname{sgn}(X_t - X_j) = 1 \\ \text{if}\,(X_t - X_j) = 0, & \operatorname{sgn}(X_t - X_j) = 0 \\ \text{if}\,(X_t - X_j) < 0, & \operatorname{sgn}(X_t - X_j) = -1. \end{array} \tag{6}$$

$U_{t,N}$ counts the times for which members of the first sample are over those of the second. In the Pettitt's test, the null hypothesis has no changing point. The test statistic K_N and the associated probability (P) are derived as below:

$$K_N = \max_{1 \le t \le N} \left| U_{t,N} \right| \tag{7}$$

$$P \cong 2 \exp\left\{ -6 (K_N)^2 / \left(N^3 + N^2 \right) \right\}. \tag{8}$$

Step 3. Estimating the total variation in run-off (ΔR_c) and sediment discharge (ΔS_c) over the period following the change-point years.

Once the change-point year (T_b) has been determined in Step 2, regression equations can be developed based on the data points for the period before T_b:

$$\sum R = a_1 \sum P + b_1 \tag{9}$$

$$\sum S = a_2 \sum P + b_2. \tag{10}$$

The cumulative run-off (ΣR_c) and sediment discharge (ΣS_c) at T_n year are derived through taking the cumulative precipitation over the

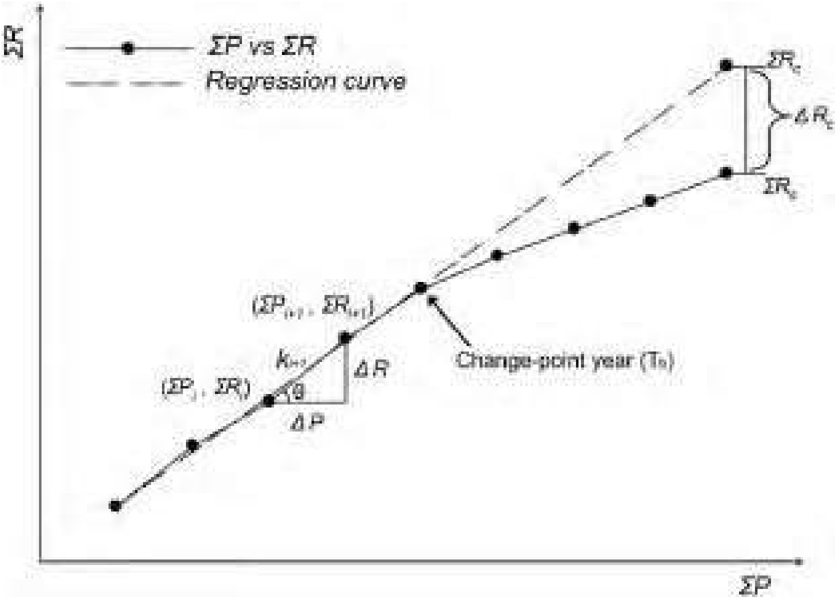


FIGURE 1 Sketch of the double mass curve of precipitation versus run-off

whole study period (Σ*P*) as the input of the regression Equations 9 and 10. The total variation of run-off (ΔR_c) and sediment (ΔS_c) over the time following the change-point year can then be expressed as (Figure 1)

$$\Delta R_c = \sum R_c - \sum R \tag{11}$$

$$\Delta S_c = \sum S_c - \sum S. \tag{12}$$

Then, the run-off or sediment reduction rate (η_R or η_S) can be expressed as

$$\eta_R = \frac{\Delta R_c}{\sum R_c} \times 100\% \tag{13}$$

$$\eta_S = \frac{\Delta S_c}{\sum S_c} \times 100\%. \tag{14}$$

Step 4. Identifying the relative effect of precipitation and anthropogenic disturbances on changes in streamflow or sediment discharge.

The relative influence of precipitation and anthropogenic disturbances on streamflow and sediment shifts can be determined according to the procedure presented in Table 1. In the table, $\overline{R_b}$ and $\overline{R_a}$ represent observed mean annual run-off or sediment for a certain period before and after the transition year. Total change in run-off or sediment (Δ*R*) equals the discrepancy between $\overline{R_b}$ and $\overline{R_a}$. Predicted mean annual run-off and sediment for a certain period (e.g., say 10 years) after the change-point year, $\overline{R_{ca}}$ can then be derived on the basis of the run-off and sediment predicted by Equations 9 and 10 for individual years. The discrepancy between and $\overline{R_b}$ and $\overline{R_{ca}}$ indicates the effect of precipitation change (Δ*P*), whereas the difference of $\overline{R_a}$ and $\overline{R_{ca}}$ or between ΔR and Δ*P* is attributed to human interventions.

with an area of 344,000 km^2. In this study, annual precipitation was collected at 33 meteorological stations across the region. They were provided by the National Meteorological Information Centre and China Meteorological Administration. Annual streamflow and sediment discharge for the study region were derived on the basis of measurements of two key hydrological stations (i.e., Toudaoguai and Huayuankou) provided by the Chinese River Streamflow and Sediment Communiques, the Ministry of Water Resources of PRC. All the measured data underwent a strict quality control process conducted by corresponding agencies.

Annex D-2

Homogeinity Test of Rainfall Data

Station: 1

Results for the homogeneity test of rainfall data

Pettitt's test for single change-point detection

```
data:  Maximum Daily Rainfall_Station1
U* = 20, p-value = 1
alternative hypothesis: two.sided
sample estimates:
probable change point at time K
                 9
```

Buishand U test

```
data:  Maximum Daily Rainfall_Station1
U = 0.10912, n = 15, p-value = 0.5772
alternative hypothesis: true delta is not equal to 0
sample estimates:
probable change point at time K
                 9
```

Standard Normal Homogeneity Test (SNHT)

```
data:  Maximum Daily Rainfall_Station1
T = 2.1953, n = 15, p-value = 0.74
alternative hypothesis: true delta is not equal to 0
sample estimates:
probable change point at time K
                 9
```

Summary of Analysis

Station: 1

Test method	Statistics value	Critical value	Check
		Significance level 5%	
Pettitt	20.00	36.27	Homogeneous
Buishand	0.11	1.37	Homogeneous
Standard	2.20	6.40	Homogeneous

The maximum daily rainfall from station 1, were used for
checking of data homogeneity and data consistency by Homogeneity Test.
From the analysis of homogeneity test with 2 variables and by 3 mentioned methods
it is found that the computed statistics values are less than critical values in all tests, therefore it can be concluded that the maximum daily rainfall data from station 1 is on the acceptable homogeneous.

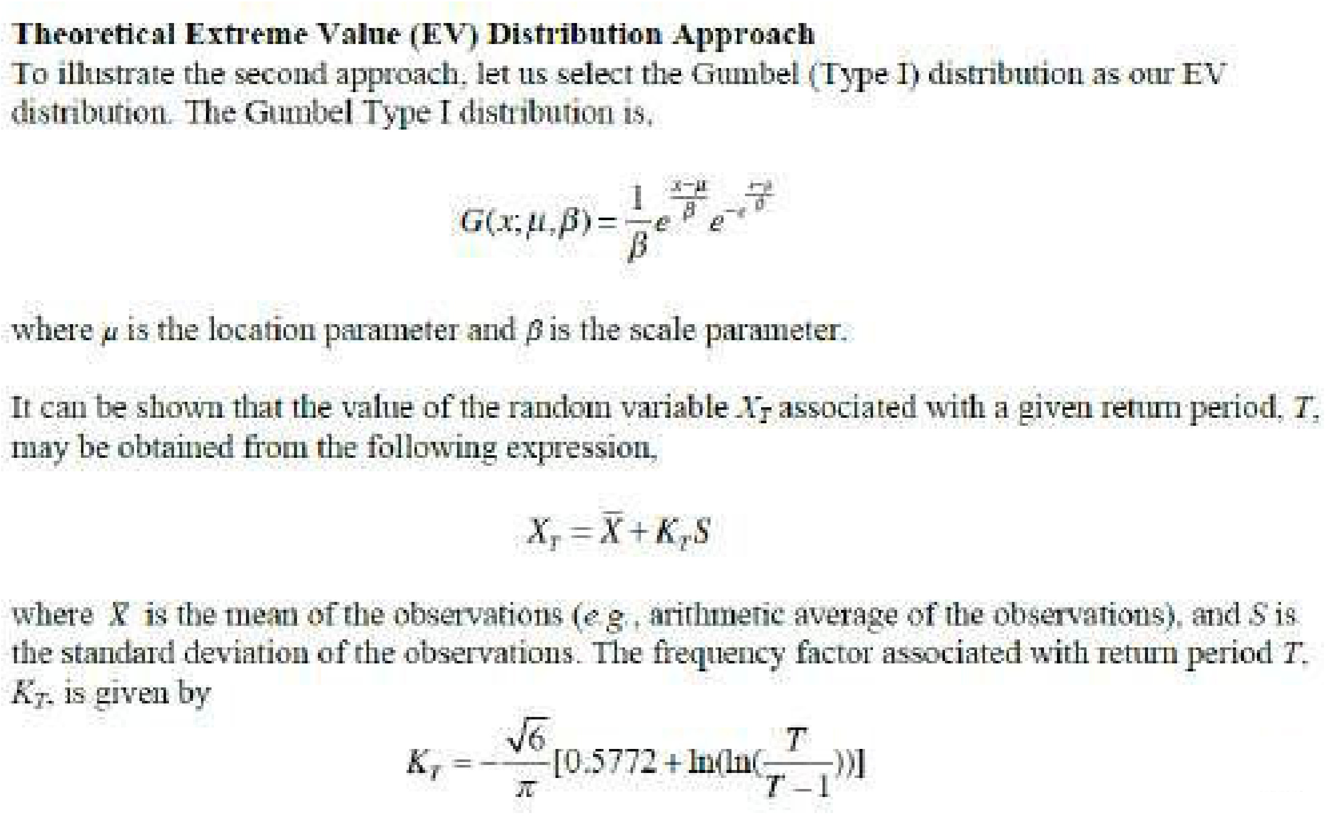
Annex D-3

Rainfall Distribution

Rainfall Distribution

The recorded maximum daily rainfall data obtained from the meteorology station is as shown in Table D3-1.

Rainfall intensity at different return periods 2, 5, 10, 20, 25, 50 and 100 years were estimated through statistical analysis by using Log-Normal Distribution, Gumbel Theoretical of Extreme Value Distribution and Log Pearson Type III Distribution then the results from the analysis were investigated by using Kolmogorov-Smirnov Test and the best goodness-of-fit method was selected, as following:



Theoretical Extreme Value (EV) Distribution Approach

To illustrate the second approach, let us select the Gumbel (Type I) distribution as our EV distribution. The Gumbel Type I distribution is,

$$G(x;\mu,\beta)=\frac{1}{\beta}e^{\frac{x-\mu}{\beta}}e^{-e^{\frac{x-\mu}{\beta}}}$$

where μ is the location parameter and β is the scale parameter.

It can be shown that the value of the random variable X_T associated with a given return period, T, may be obtained from the following expression,

$$X_T=\overline{X}+K_T S$$

where $\overline{X}$ is the mean of the observations (*e.g.*, arithmetic average of the observations), and S is the standard deviation of the observations. The frequency factor associated with return period T, K_T, is given by

$$K_T=-\frac{\sqrt{6}}{\pi}[0.5772+\ln(\ln(\frac{T}{T-1}))]$$

Log-Normal Distribution

The log-normal distribution is the probability distribution of a random variable whose logarithm is normally distributed. Let X be a random variable with a normal distribution, then Y = exp(X) has a log-normal distribution. In other words, if Y is log-normally distributed, then X = log(Y) is normally distributed. When a random variable represents a process that is the resultant of multiplicative product of many small effects each of which is positive, then it can be expressed the sum of logarithms of these small effects. The logarithm of such a random variable can be expected to follow a normal distribution. Hence, if the variable is transformed to the log domain, it is likely to follow he normal distribution. An advantage of the log-normal distribution is that it

is often useful to represent quantities that cannot have negative values. It has proven useful to model rainfall amounts, size distributions of aerosol particles, etc.

The PDF of the log-normal distribution is

$$f(x) = \frac{1}{x\sigma_y\sqrt{2\pi}} \exp\left[-\frac{(\ln x - \mu_y)^2}{2\sigma_y^2} \right] \qquad x > 0$$

The log-normal distribution has two parameters μ_y and σ_y which can be estimated by transforming all x_i's to y_i's by

$y_i = \ln x_i$

Log Pearson Type - III (LP3) Distribution

Log Pearson Type III distribution was found to give good results in numerous studies dealing with flood peak data. This distribution is the standard distribution for flood frequency analysis in the USA since its use for flood frequency analysis was recommended by the US Water

Resources Council.

LP3 is a three-parameter distribution and is widely used in hydrology. Its parameters are related to mean, standard deviation, and skewness.

$$f(x) = \frac{1}{a\Gamma(b)} \left(\frac{x-c}{a} \right)^{b-1} \exp\left(-\frac{x-c}{a} \right)$$

where *a*, *b*, and *c* are scale, shape, and location parameters, respectively, and Γ(b) is a gamma function. If $c = 0$, this distribution becomes a two-parameter gamma distribution. Parameters *a*, *b*, and *c* are related to mean, standard deviation, and coefficient of skewness as (method of moment estimates)

$a = \sigma/\sqrt{b}$

$b = (2/C_s)^2$

$c = \mu - \sigma\sqrt{b}$

To determine flood for a return period T by using the LP3 distribution, the procedure described below is followed.

First of all, the frequency factor, K_T is computed by (Chow et al. 1988):

$$K_T = z + (z^2 - 1)k + (z^3 - 6z)k^2/3 + (z^2 - 1)k^3 + zk^4 + k^5/3$$

Where $k = C_s/6$. To complete z for a given return period T, exceedance probability p is obtained as $p = 1/T$. Now, complete a variable *w* as

$$w = \sqrt{\ln(1/p^2)} \qquad 0 < p \leq 0.5$$

Now z is calculated by (Abramowitz and Stegun, 1965)

$$z = w - \frac{2.515517 + 0.802853w + 0.010328w^2}{1 + 1.432788w + 0.189269w^2 + 0.001308w^3}$$

when p > 0.5, p in eq. (10.41) is replaced by (1-p) and the negative sign is put before z computed by eq. (10.42). Now, by following the frequency factor method, the flood for the return period T years is computed by:

$$y_T = \bar{y} + K_T s_y$$

:

Table D3-1: Maximum Daily Rainfall

Station: 1	
Year	Maximum Daily Rainfall
	(mm)
2007	126.90
2008	93.18
2009	96.63
2010	74.60
2011	121.09
2012	40.05
2013	61.23
2014	135.03
2015	176.40
2016	74.75
2017	78.28
2018	62.57
2019	43.90
2020	108.72
2021	74.82

Results of Rainfall Distribution Analysis using Log Pearson Type 3, Gumbel EV1 and Log-Normal Method with Goodness-of-Fit Kolmogorov-Smirnov Test

```
 INPUT FILE: INPUT.TXT   (NON-ZERO DATA =  15  , ZERO DATA =   0)
OUTPUT FILE: OUTPUT.LP3

                         LOG-PEARSON TYPE 3 DISTRIBUTION

                           METHOD OF MOMENT (INDIRECT)

         ALPHA           -.04649             M1              4.43580
         BETA           78.62656             M2               .16992
         GAMMA           8.09092             SKEW            -.22555

   SKEW IS NEGATIVE - DISTRIBUTION HAS AN UPPER BOUND

                         T,YEARS     T-ADJUST     XT(MM)

                            2.00         2.00     85.7361
                            5.00         5.00    119.8583
                           10.00        10.00    141.6147
                           20.00        20.00    161.8243
                           25.00        25.00    168.1138
                           50.00        50.00    187.1717
                          100.00       100.00    205.6877
                          200.00       200.00    223.8203
                          500.00       500.00    247.3706
                         1000.00      1000.00    264.9533


                             KOLMOGOROV-SMIRNOV TEST

            M     XT(MM)   F'(X)     F(X)ADJ      F(X)        D

            1   176.4000      .0625      .0297      .0297      .0328
            2   135.0300      .1250      .1241      .1241      .0009
            3   126.9000      .1875      .1610      .1610      .0265
            4   121.0900      .2500      .1927      .1927      .0573
            5   108.7200      .3125      .2773      .2773      .0352
            6    96.6300      .3750      .3843      .3843      .0093
            7    93.1800      .4375      .4191      .4191      .0184
            8    78.2800      .5000      .5869      .5869      .0869
            9    74.8200      .5625      .6283      .6283      .0658
           10    74.7500      .6250      .6291      .6291      .0041
           11    74.6000      .6875      .6309      .6309      .0566
           12    62.5700      .7500      .7719      .7719      .0219
           13    61.2300      .8125      .7867      .7867      .0258
           14    43.9000      .8750      .9379      .9379      .0629
           15    40.0500      .9375      .9587      .9587      .0212
```

```
                  D MAX       =    .0869
                  D CRITICAL =    .3400
              ACCEPTED AT 0.05 SIGNIFICANCE LEVEL
```

```
 INPUT FILE: INPUT.TXT   (NON-ZERO DATA =  15   , ZERO DATA =   0)
OUTPUT FILE: OUTPUT.EV1

                        EXTREME VALUE TYPE I DISIBUTION


                                METHOD OF MOMENT

         ALPHA              .03460             M1              91.20999
         BETA             74.52733             M2            1374.37700
                                               SKEW              .62049

                           T,YEARS     T-ADJUST     XT(MM)

                              2.00         2.00     85.1215
                              5.00         5.00    117.8837
                             10.00        10.00    139.5750
                             20.00        20.00    160.3819
                             25.00        25.00    166.9822
                             50.00        50.00    187.3143
                            100.00       100.00    207.4964
                            200.00       200.00    227.6048
                            500.00       500.00    254.1340
                           1000.00      1000.00    274.1841



                             KOLMOGOROV-SMIRNOV TEST

            M     XT(MM)   F'(X)      F(X)ADJ      F(X)        D

            1   176.4000       .0625       .0290       .0290       .0335
            2   135.0300       .1250       .1160       .1160       .0090
            3   126.9000       .1875       .1507       .1507       .0368
            4   121.0900       .2500       .1810       .1810       .0690
            5   108.7200       .3125       .2639       .2639       .0486
            6    96.6300       .3750       .3722       .3722       .0028
            7    93.1800       .4375       .4082       .4082       .0293
            8    78.2800       .5000       .5845       .5845       .0845
            9    74.8200       .5625       .6284       .6284       .0659
           10    74.7500       .6250       .6293       .6293       .0043
           11    74.6000       .6875       .6312       .6312       .0563
           12    62.5700       .7500       .7796       .7796       .0296
           13    61.2300       .8125       .7949       .7949       .0176
           14    43.9000       .8750       .9442       .9442       .0692
           15    40.0500       .9375       .9630       .9630       .0255
```

```
      D MAX      =   .0845
      D CRITICAL =   .3400
ACCEPTED AT 0.05 SIGNIFICANCE LEVEL
```

```
 INPUT FILE: INPUT.TXT   (NON-ZERO DATA =  15   , ZERO DATA =    0)
OUTPUT FILE: OUTPUT.LN3

                      THREE PARAMETER LOGNORM DISTRIBUTION

                                METHOD OF MOMENTS

                       A                           -56.80856
                       MEAN OF LN(X-A)               4.96692
                       VARIANCE OF LN(X-A)            .06084
                       SKEW OF X                      .76709

                         T,YEARS     T ADJUST     XT(MM)

                            2.00        2.00     86.7750
                            5.00        5.00    119.8944
                           10.00       10.00    140.1646
                           20.00       20.00    158.6404
                           25.00       25.00    164.3404
                           50.00       50.00    181.5085
                          100.00      100.00    198.0836
                          200.00      200.00    214.2595
                          500.00      500.00    235.2422
                         1000.00     1000.00    250.9216


                             KOLMOGOROV-SMIRNOV TEST

            M     XT(MM)   F'(X)     F(X)ADJ      F(X)        D

            1   176.4000      .0625      .0246      .0246      .0379
            2   135.0300      .1250      .1201      .1201      .0049
            3   126.9000      .1875      .1589      .1589      .0286
            4   121.0900      .2500      .1925      .1925      .0575
            5   108.7200      .3125      .2821      .2821      .0304
            6    96.6300      .3750      .3939      .3939      .0189
            7    93.1800      .4375      .4298      .4298      .0077
            8    78.2800      .5000      .5976      .5976      .0976
            9    74.8200      .5625      .6377      .6377      .0752
           10    74.7500      .6250      .6386      .6386      .0136
           11    74.6000      .6875      .6403      .6403      .0472
           12    62.5700      .7500      .7729      .7729      .0229
           13    61.2300      .8125      .7865      .7865      .0260
           14    43.9000      .8750      .9248      .9248      .0498
           15    40.0500      .9375      .9448      .9448      .0073
```

```
       D MAX      =   .0976
       D CRITICAL =   .3400
ACCEPTED AT 0.05 SIGNIFICANCE LEVEL
```

Smirnov Kolmogorov Test for Log Pearson Type III Distribution

Significance level	D CRITICAL (Dc)	D MAX (Dn)	Dn < Dc
0.05	0.340	0.0869	Accepted

Smirnov Kolmogorov Test for Gumbel Distribution

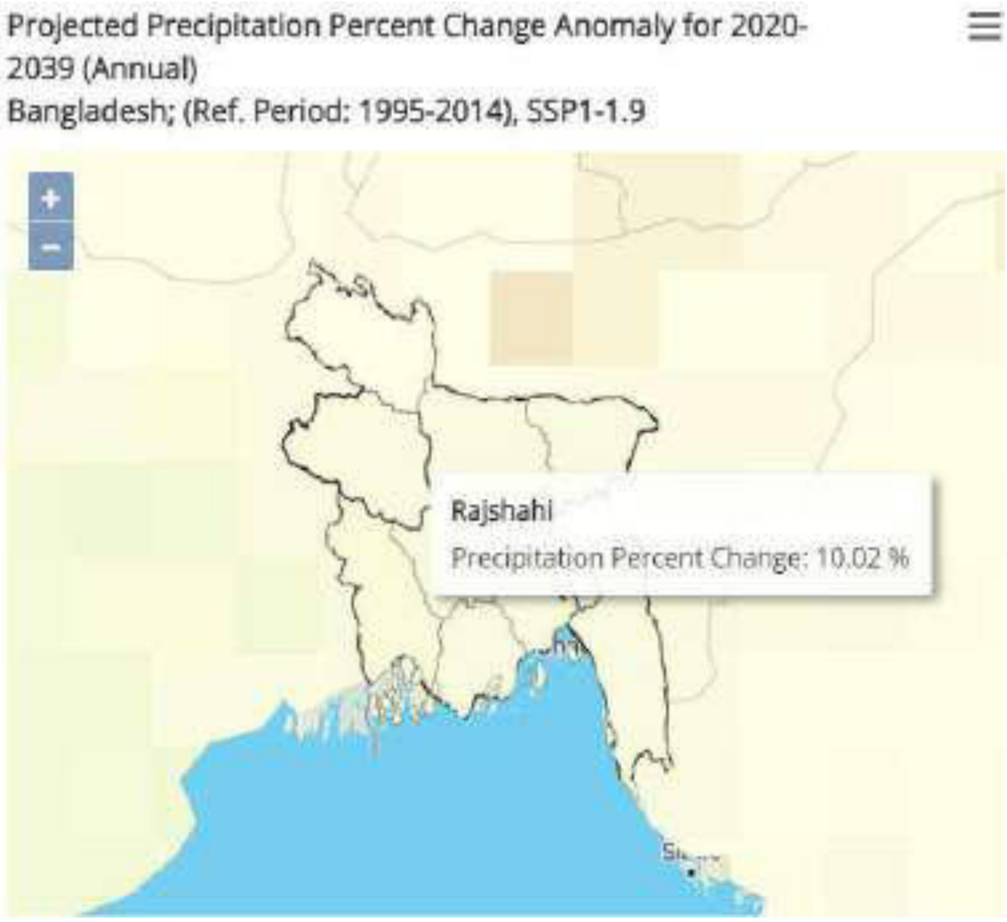
Significance level	D CRITICAL (Dc)	D MAX (Dn)	Dn < Dc
0.05	0.340	0.0845	Accepted

Smirnov Kolmogorov Test for Log Normal Distribution

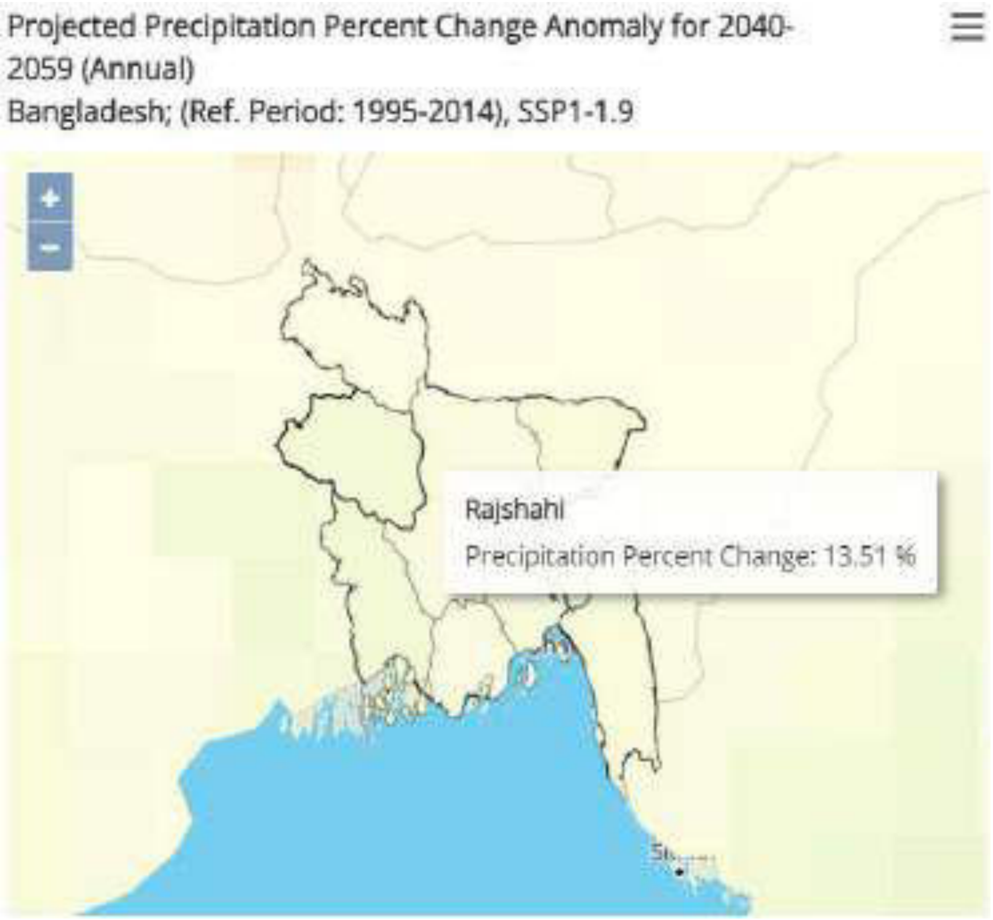
Significance level	D CRITICAL (Dc)	D MAX (Dn)	Dn < Dc
0.05	0.340	0.0976	Accepted

When a test result can accept the suitability of more than one distribution function and use criteria to determine whether
Functions that can be best adapted to the data have the least value Dn.

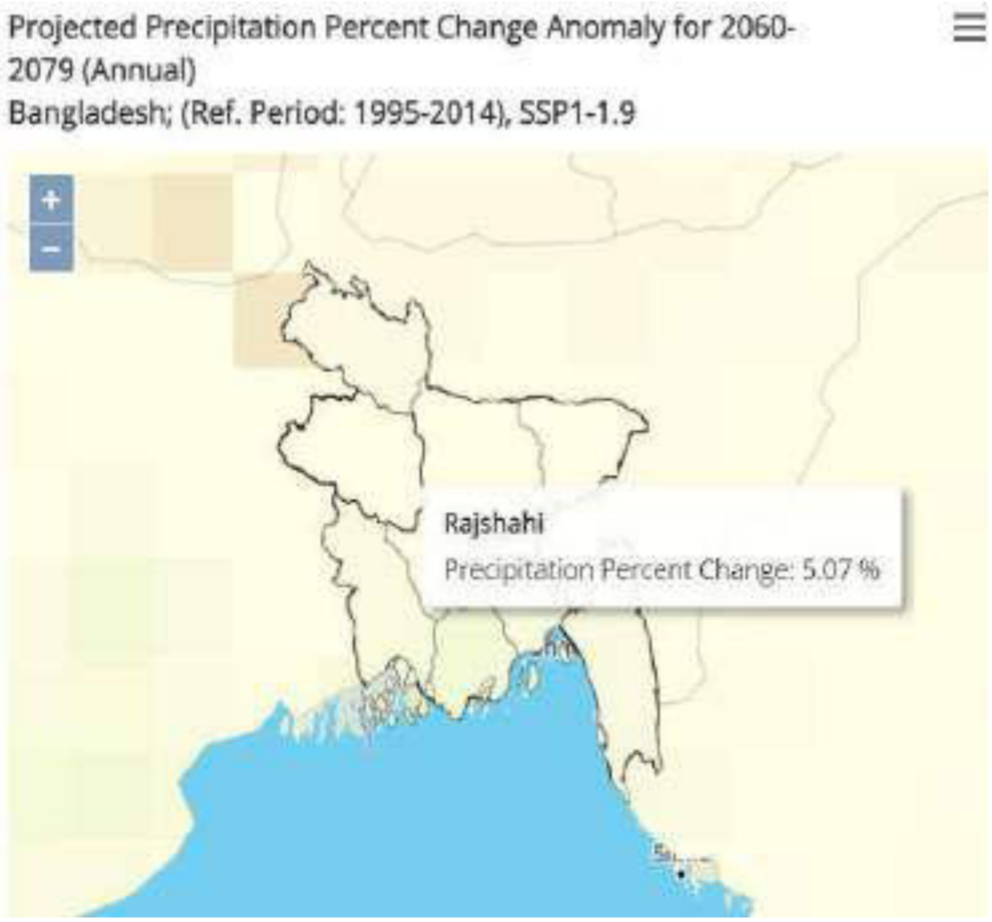
From the calculation analysis and taking into account the physical aspects of the field, it can be determined the design flood discharge analysis can use the rainfall design by Gumbel Distribution method. So the results of the calculation of rainfall design with various time can be seen in the following table.



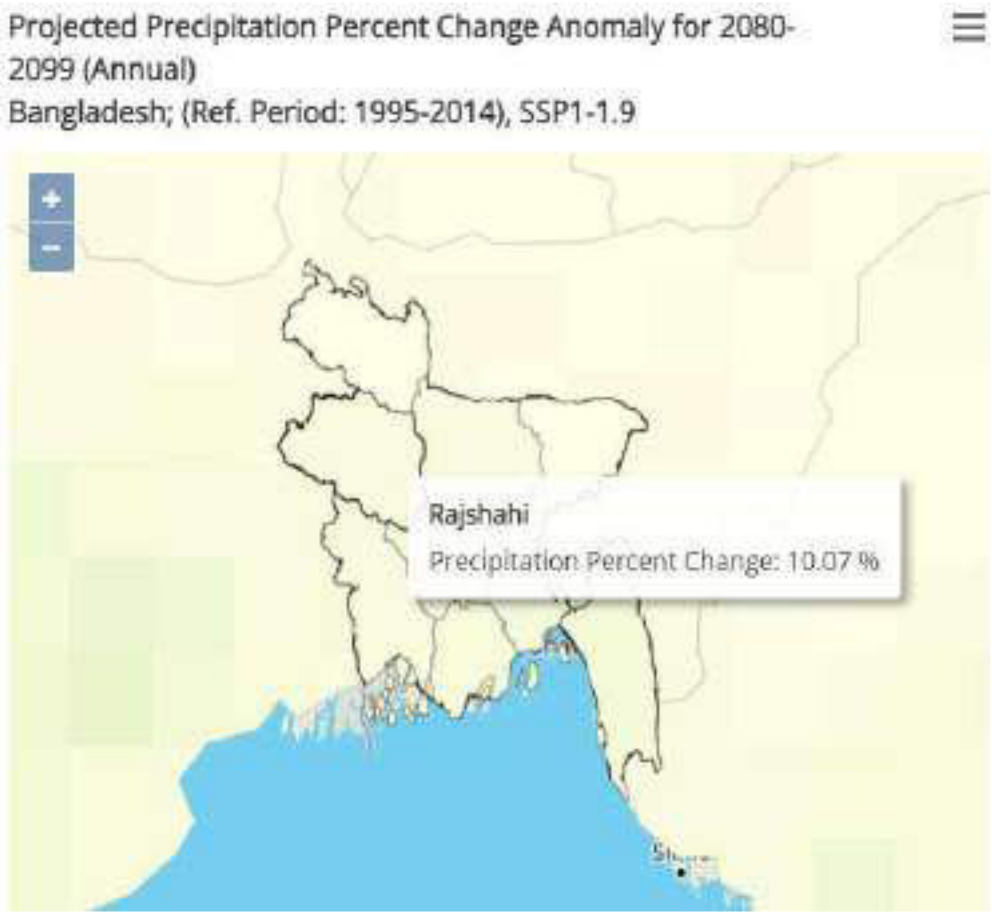
Projected Precipitation Percent Change Anomaly for 2020-2039 (Annual)
Bangladesh; (Ref. Period: 1995-2014), SSP1-1.9



Projected Precipitation Percent Change Anomaly for 2040-2059 (Annual)
Bangladesh; (Ref. Period: 1995-2014), SSP1-1.9



Projected Precipitation Percent Change Anomaly for 2060-2079 (Annual)
Bangladesh; (Ref. Period: 1995-2014), SSP1-1.9



Projected Precipitation Percent Change Anomaly for 2080-2099 (Annual)
Bangladesh; (Ref. Period: 1995-2014), SSP1-1.9

Projected Change in Annual Precipitation as Percentage

	Annual Precipitation (%)			
	2020-2039	2040-2059	2060-2079	2080-2099
Bangladesh	7.6	9.12	4.48	7.46
Barisal	10.39	9.89	13.84	11.58
Chittagong	8.89	10.97	8.72	12.31
Rajshahi	10.02	13.51	5.07	10.07
Dhaka	9.72	10.08	3.69	9.43
Rangpur	5.07	6.17	0.69	3.81
Khulna	11.54	14.61	8.84	10.17
Sylhet	7.86	10.9	3.7	3.9

** Project site is located in Rajshahi Division

Ref.
https://climateknowledgeportal.worldbank.org/country/bangladesh/climate-data-projections

As presented from (https://climateknowledgeportal.worldbank.org/country/bangladesh/climate-data-projections) "Projected change in annual precipitation as percentage for Rajshahi Division". Predict rainfall increase +15.42% by the 2047's.

From predicted rainfall increase +15.42% by 2047 or about 25 years from present (solar power project life).
So, estimations of maximum daily rainfall will be made based on this assumption; due to future climate change rainfall intensity is considered to increase by 15.42% for the future of 25 years.

The estimated maximum daily rainfall intensity values by Gumbel Distribution method with effect from future Climate Change Factor as predicted by The World Bank Group will be used for further estimation of maximum flood discharges.

Table D3-2: Estimated max daily rainfall from Gumbel Distribution at various return periods without effect from future climate change in column (3) and with effect from future climate change in column (4)

Station: 1

(1)	(2)	(3)	(4)
No.	Return Period; Tr	Estimated Max Daily Rainfall Depth; (Without effect from climate change)	Estimated Max Daily Rainfall Depth; (With effect from climate change; 15.42% in the period of 25 yr project life
	(Year)	(mm)	(mm)
1	2	85.1215	98.2472
2	5	117.8837	136.0614
3	10	139.5750	161.0975
4	20	160.3819	185.1128
5	25	166.9822	192.7309
6	50	187.3143	216.1982
7	100	207.4964	239.4923

Annex D-4

Peak Discharge Calculation using the NRCS method by Hydrology Studio software

Basin Model


WATERSHED MAP
LEGEND
Sub-Watershed
Main Water Course
Toe Slope of Road

Hydrograph by Return Period

Hydrology Studio v 3.0.0.26

Project Name:

08-25-2022

Hyd. No.	Hydrograph Type	Hydrograph Name	Peak Outflow (cms)							
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
1	NRCS Runoff	1A					0.4437			
2	NRCS Runoff	1B					0.4722			
3	NRCS Runoff	1C					0.1327			
4	NRCS Runoff	2A					0.3390			
5	NRCS Runoff	2B					0.1815			
6	NRCS Runoff	2C					0.5414			
7	NRCS Runoff	3A					0.8660			
8	NRCS Runoff	4A					0.2932			
9	NRCS Runoff	4B					0.3793			
10	NRCS Runoff	5A					0.3371			
11	NRCS Runoff	6A					0.3618			
12	NRCS Runoff	7A					0.8705			
13	NRCS Runoff	8A					0.5427			
14	NRCS Runoff	8B					0.4936			
15	NRCS Runoff	9A					0.9925			
16	NRCS Runoff	10A					0.3078			
17	NRCS Runoff	11A					0.7677			
18	NRCS Runoff	12A					0.4143			
19	NRCS Runoff	12B					0.3335			
20	NRCS Runoff	13A					0.1030			
21	NRCS Runoff	13B					0.1240			
22	NRCS Runoff	13C					0.0381			
23	NRCS Runoff	13D					0.3810			

Hydrograph 10-yr Summary

Hydrology Studio v 3.0.0.26

Project Name:

08-25-2022

Hyd. No.	Hydrograph Type	Hydrograph Name	Peak Flow (cms)	Time to Peak (hrs)	Hydrograph Volume (cum)	Inflow Hyd(s)	Maximum Elevation (m)	Maximum Storage (cum)
1	NRCS Runoff	1A	0.4437	12.02	1,246	----		
2	NRCS Runoff	1B	0.4722	12.02	1,326	----		
3	NRCS Runoff	1C	0.1327	11.95	270	----		
4	NRCS Runoff	2A	0.3390	12.30	2,023	----		
5	NRCS Runoff	2B	0.1815	12.15	775	----		
6	NRCS Runoff	2C	0.5414	12.10	1,958	----		
7	NRCS Runoff	3A	0.8660	12.12	3,346	----		
8	NRCS Runoff	4A	0.2932	12.00	753	----		
9	NRCS Runoff	4B	0.3793	12.13	1,559	----		
10	NRCS Runoff	5A	0.3371	12.00	866	----		
11	NRCS Runoff	6A	0.3618	12.02	1,016	----		
12	NRCS Runoff	7A	0.8705	12.35	5,703	----		
13	NRCS Runoff	8A	0.5427	12.13	2,231	----		
14	NRCS Runoff	8B	0.4936	12.18	2,347	----		
15	NRCS Runoff	9A	0.9925	12.28	5,700	----		
16	NRCS Runoff	10A	0.3078	12.00	791	----		
17	NRCS Runoff	11A	0.7677	12.18	3,650	----		
18	NRCS Runoff	12A	0.4143	12.65	3,915	----		
19	NRCS Runoff	12B	0.3335	12.00	857	----		
20	NRCS Runoff	13A	0.1030	11.98	242	----		
21	NRCS Runoff	13B	0.1240	12.03	368	----		
22	NRCS Runoff	13C	0.0381	11.93	70.6	----		
23	NRCS Runoff	13D	0.3810	12.78	4,027	----		

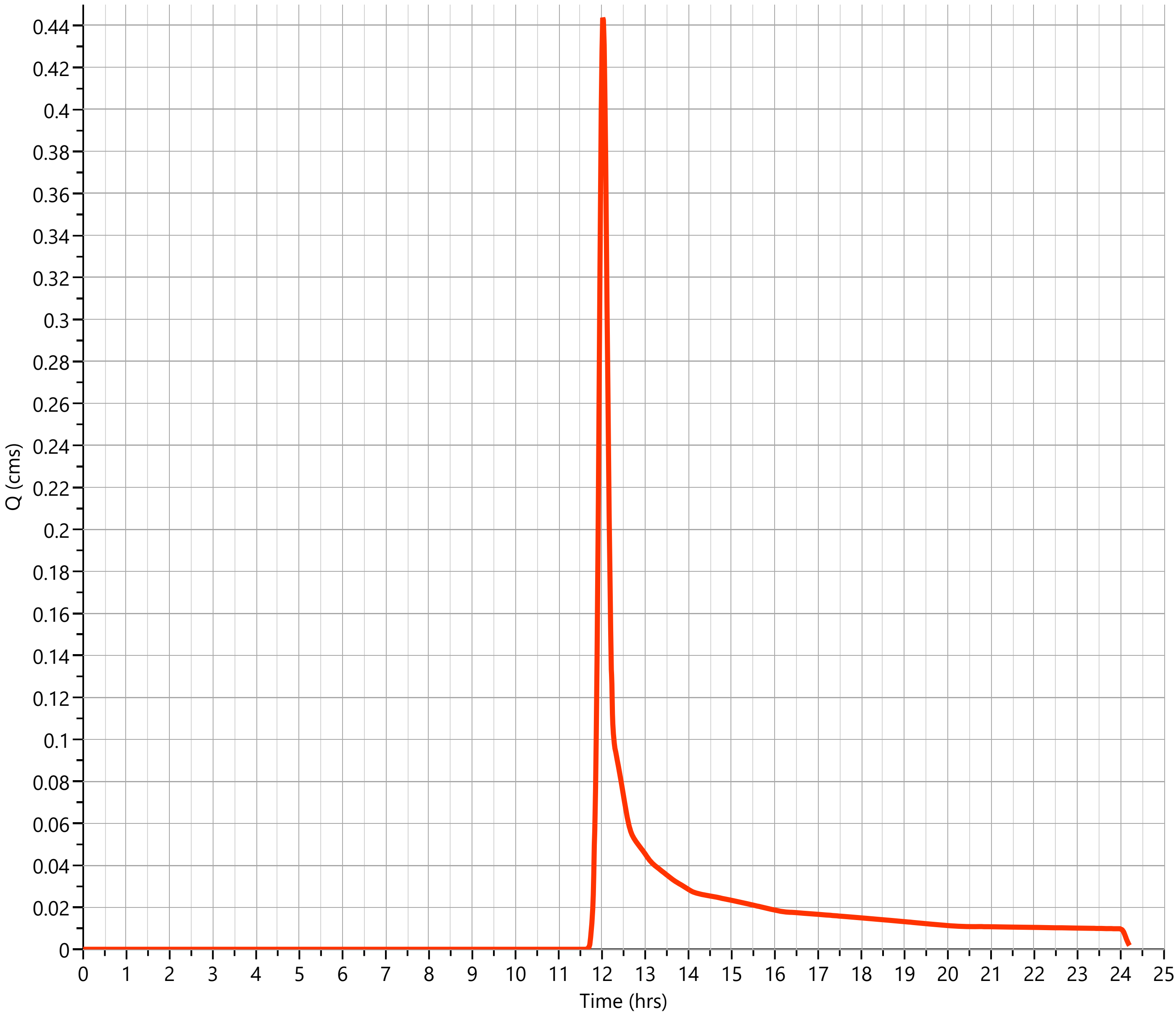
Hydrograph Report

1A

Hyd. No. 1

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.4437 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.02 hrs
Time Interval	= 1 min	Runoff Volume	= 1,246 cum
Drainage Area	= 3.9 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 10.33 min
Basin Slope	= 0.43 %	Hydraulic Length	= 230.91 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

Qp = 0.444 cms



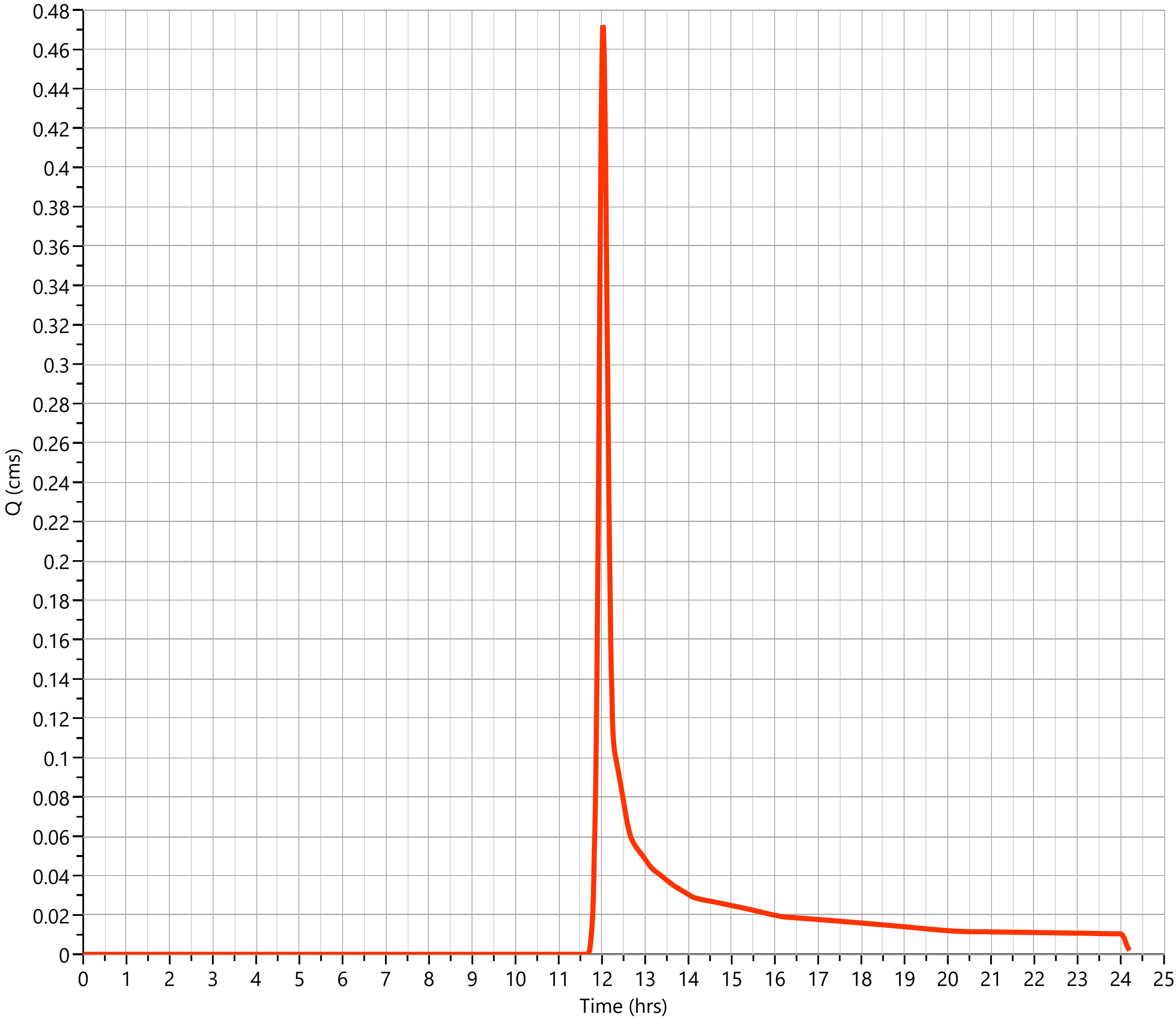
Hydrograph Report

1B

Hyd. No. 2

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.4722 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.02 hrs
Time Interval	= 1 min	Runoff Volume	= 1,326 cum
Drainage Area	= 4.15 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 10.4 min
Basin Slope	= 0.4 %	Hydraulic Length	= 224.47 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

Qp = 0.472 cms

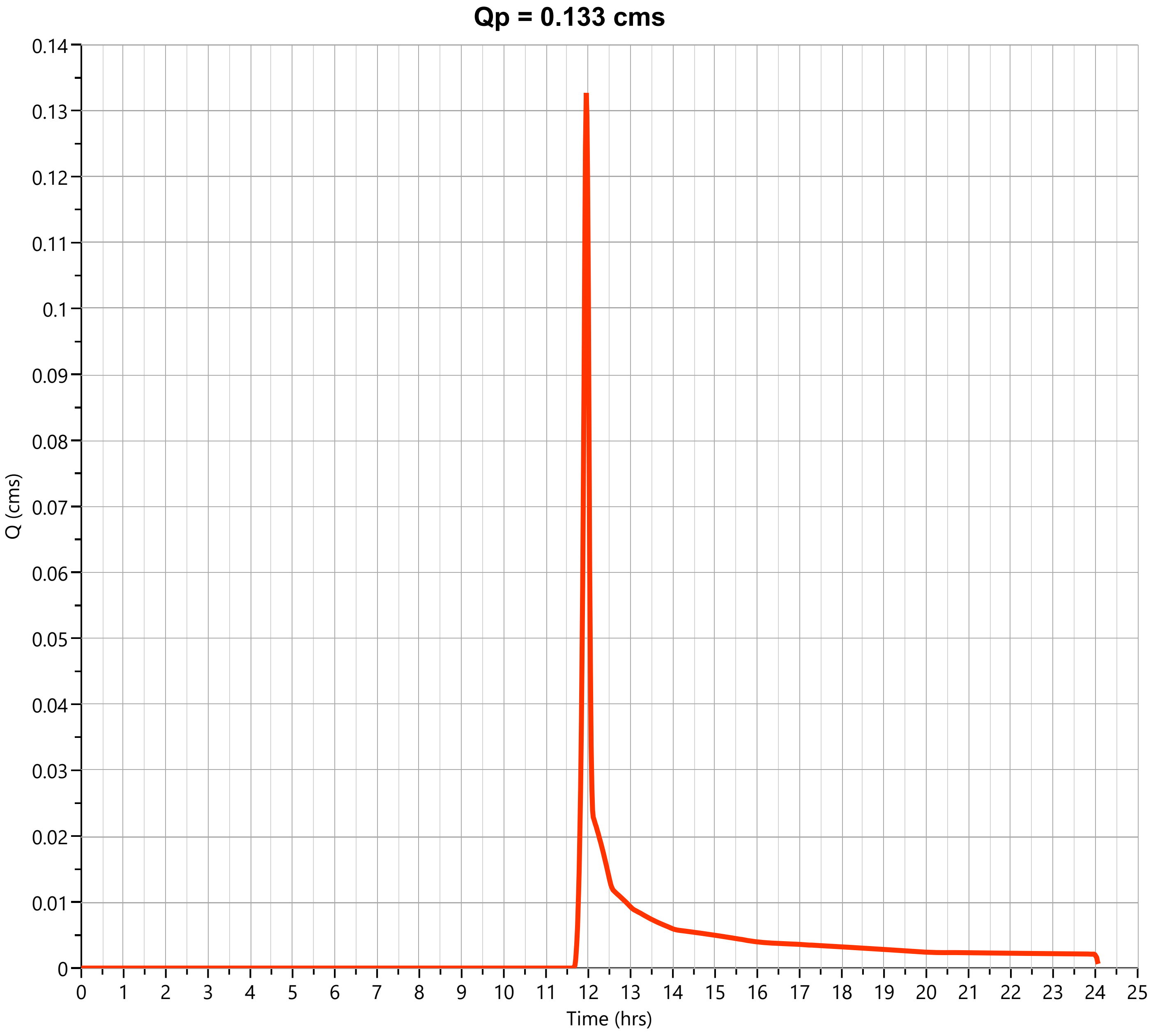


Hydrograph Report

1C

Hyd. No. 3

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.1327 cms
Storm Frequency	= 10-yr	Time to Peak	= 11.95 hrs
Time Interval	= 1 min	Runoff Volume	= 270 cum
Drainage Area	= 0.86 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 4.18 min
Basin Slope	= 0.53 %	Hydraulic Length	= 79.25 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

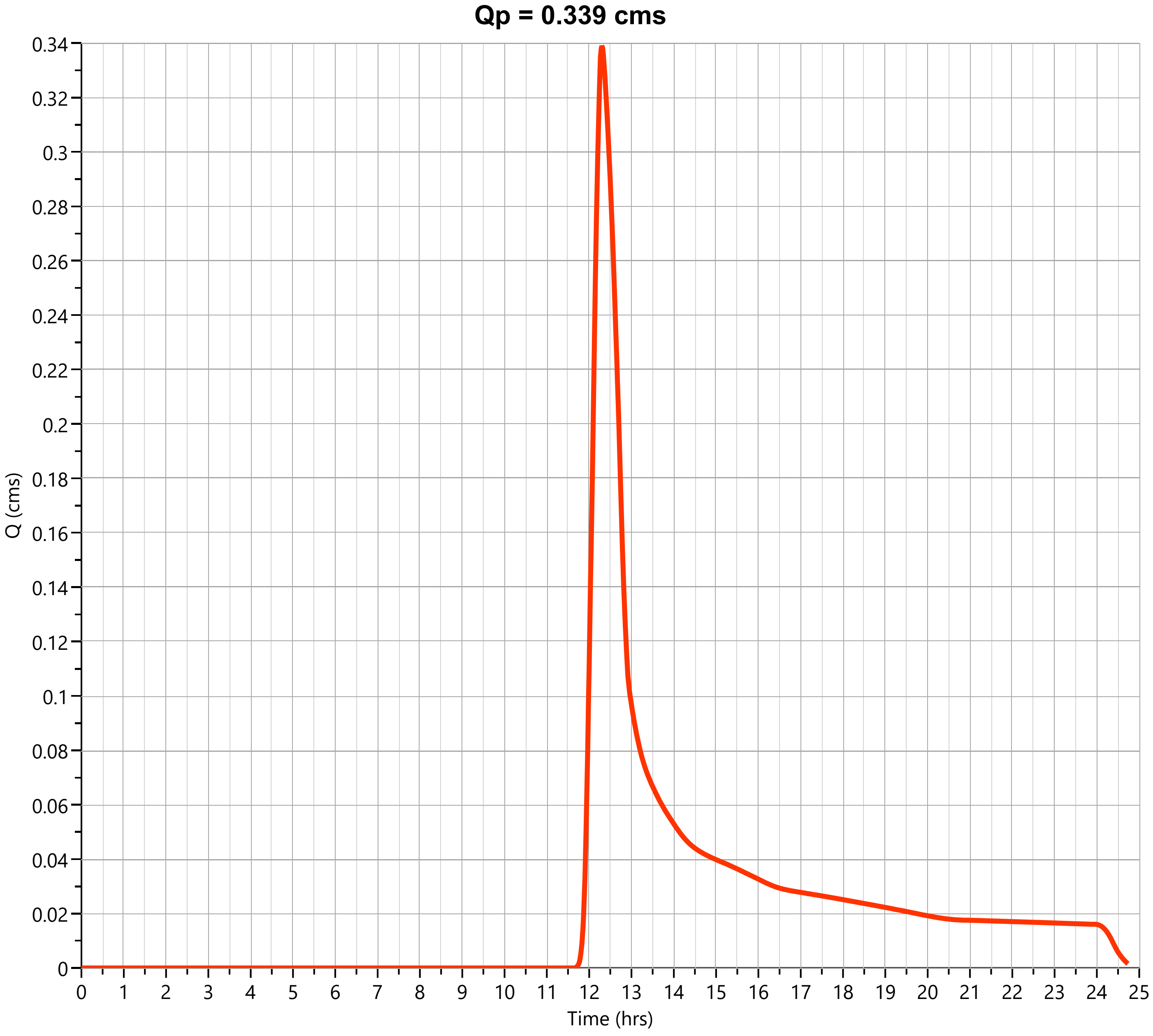


Hydrograph Report

2A

Hyd. No. 4

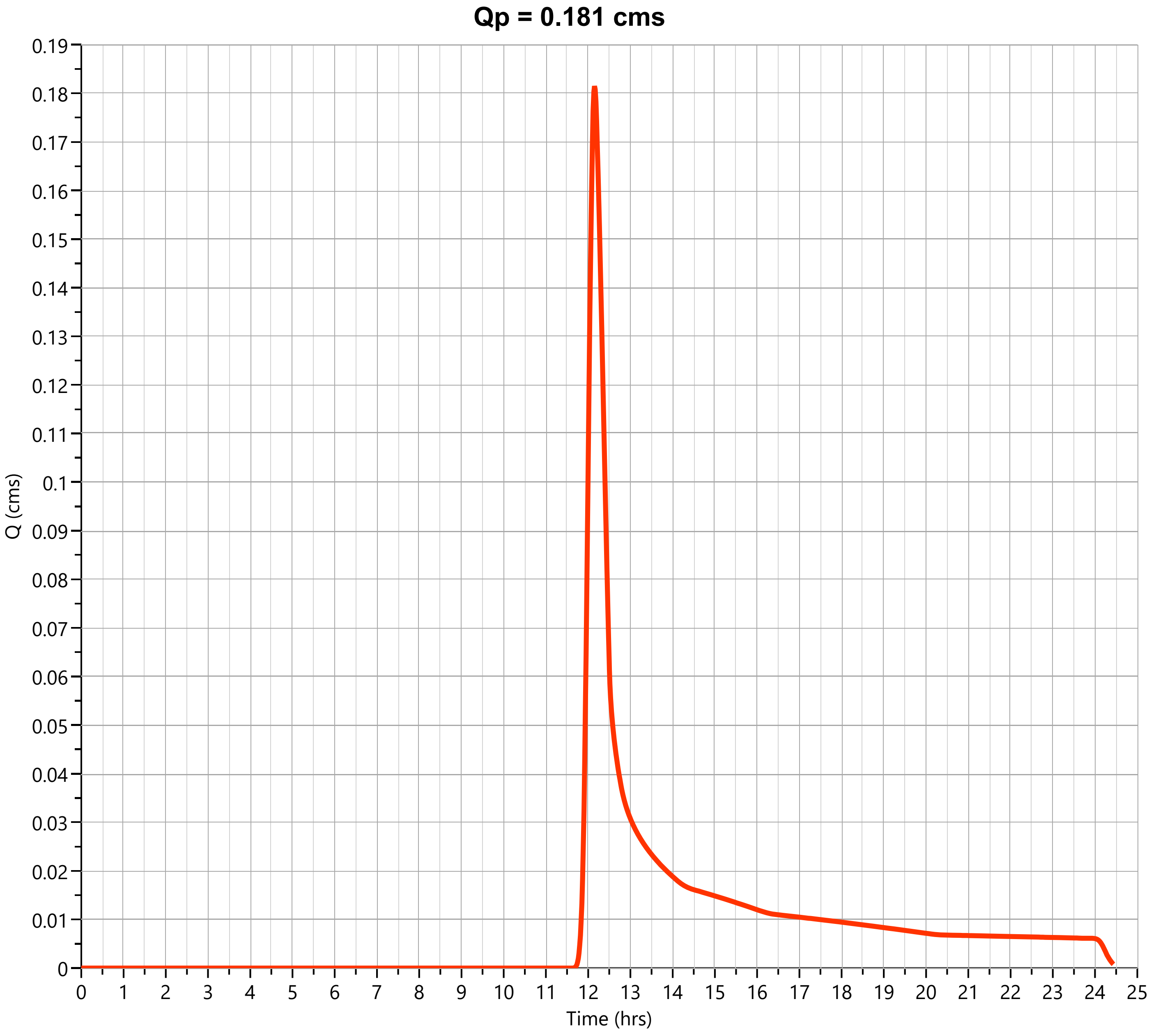
Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.3390 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.30 hrs
Time Interval	= 1 min	Runoff Volume	= 2,023 cum
Drainage Area	= 6.41 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 37.04 min
Basin Slope	= 0.03 %	Hydraulic Length	= 320.11 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208



2B

Hyd. No. 5

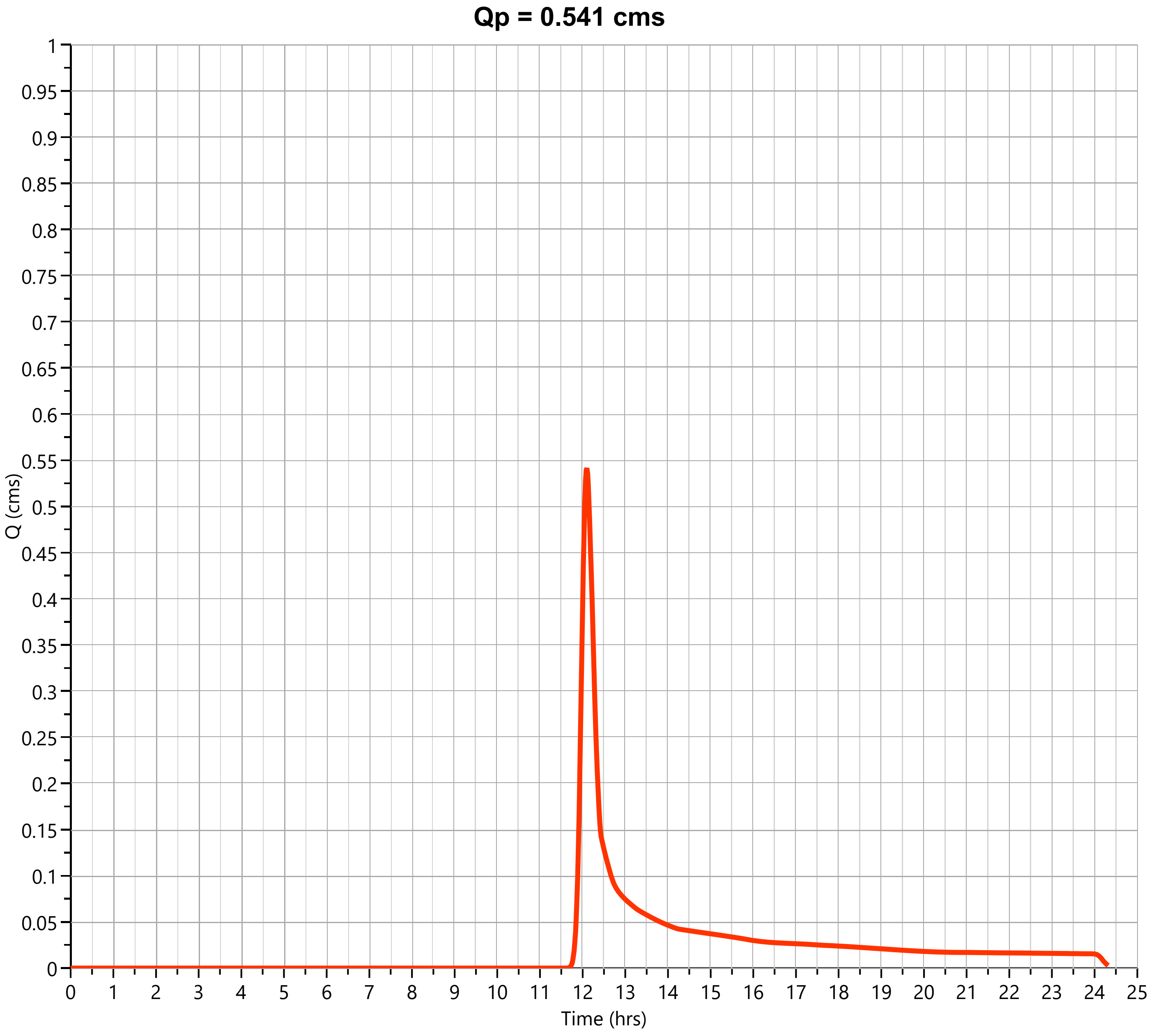
Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.1815 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.15 hrs
Time Interval	= 1 min	Runoff Volume	= 775 cum
Drainage Area	= 2.49 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 22.89 min
Basin Slope	= 0.12 %	Hydraulic Length	= 342.73 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208



2C

Hyd. No. 6

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.5414 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.10 hrs
Time Interval	= 1 min	Runoff Volume	= 1,958 cum
Drainage Area	= 6.31 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 16.86 min
Basin Slope	= 0.2 %	Hydraulic Length	= 297.31 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208



Hydrograph Report

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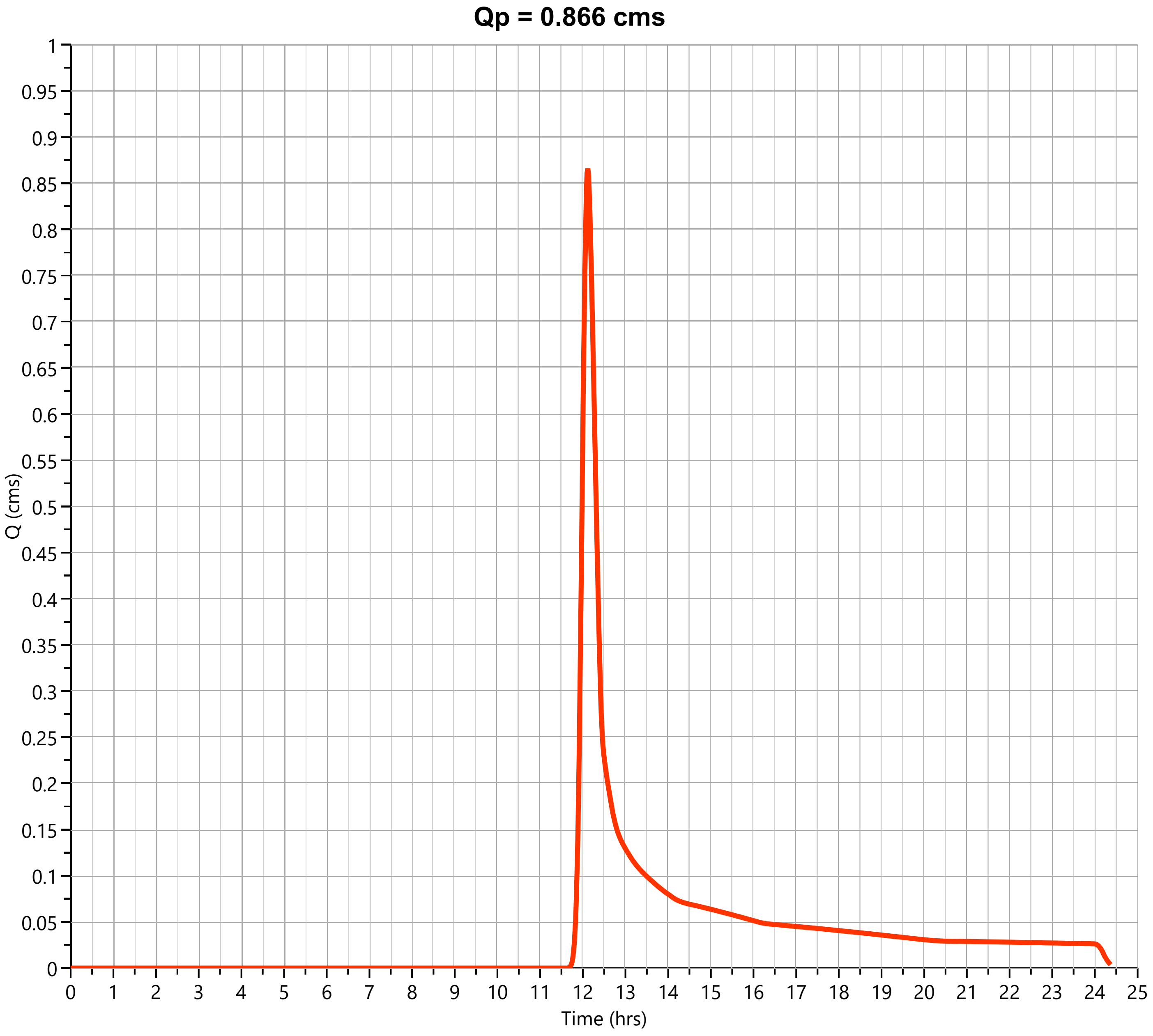
08-25-2022

3A

Hyd. No. 7

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.8660 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.12 hrs
Time Interval	= 1 min	Runoff Volume	= 3,346 cum
Drainage Area	= 10.66 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 18.84 min
Basin Slope	= 0.26 %	Hydraulic Length	= 391.69 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

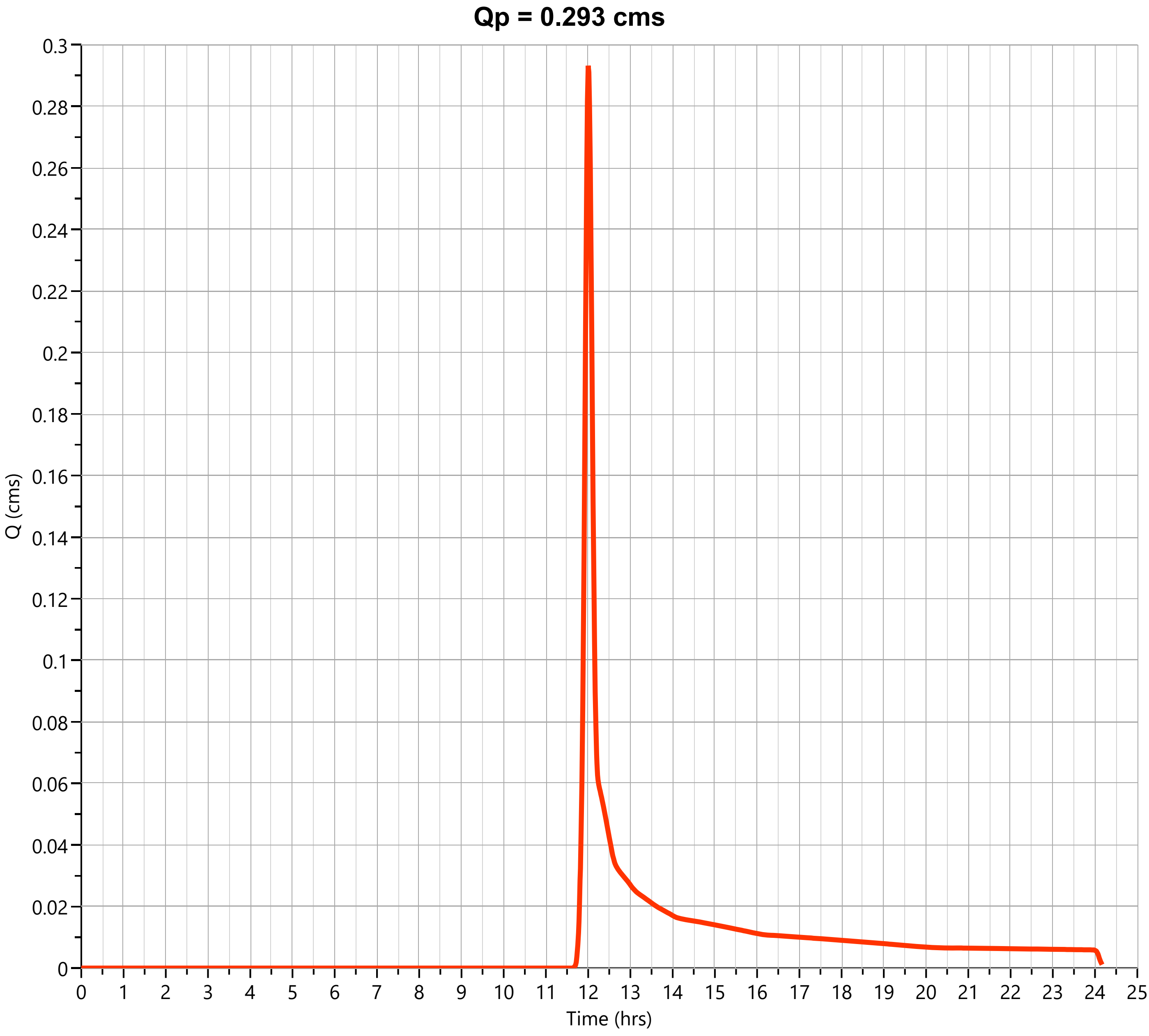


Hydrograph Report

4A

Hyd. No. 8

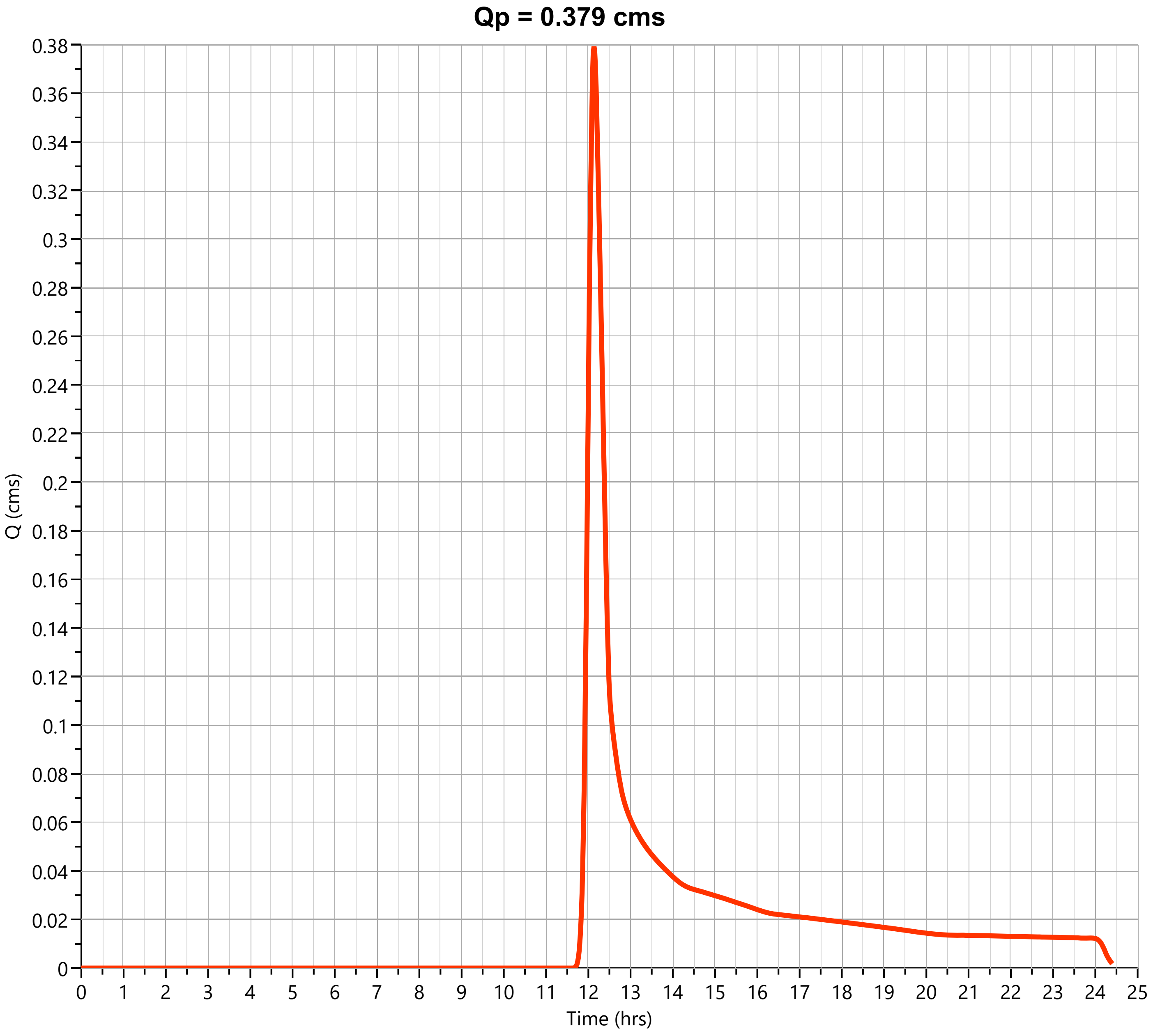
Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.2932 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.00 hrs
Time Interval	= 1 min	Runoff Volume	= 753 cum
Drainage Area	= 2.4 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 8.94 min
Basin Slope	= 0.31 %	Hydraulic Length	= 162.43 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208



4B

Hyd. No. 9

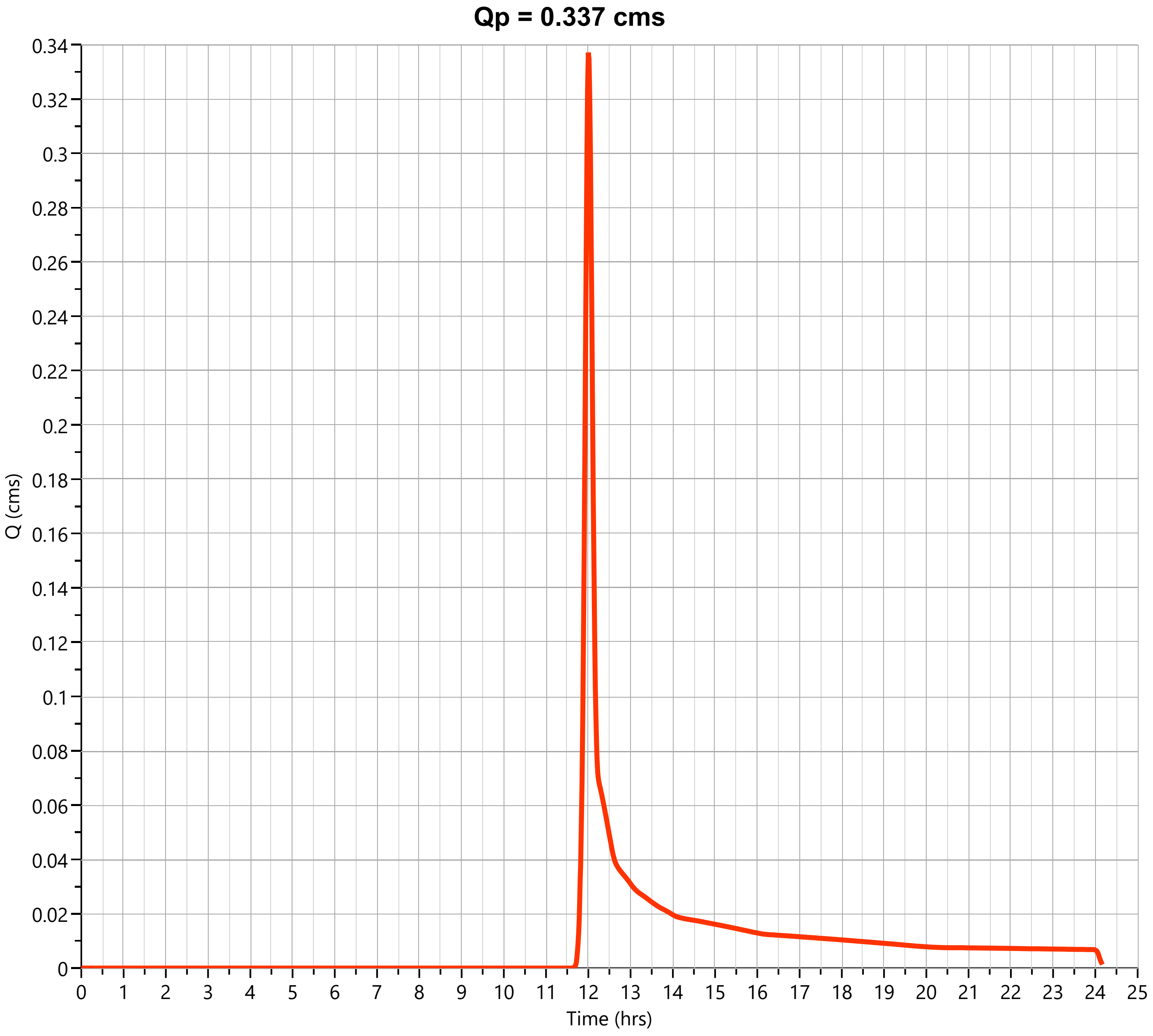
Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.3793 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.13 hrs
Time Interval	= 1 min	Runoff Volume	= 1,559 cum
Drainage Area	= 4.92 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 20.96 min
Basin Slope	= 0.15 %	Hydraulic Length	= 341.77 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208



5A

Hyd. No. 10

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.3371 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.00 hrs
Time Interval	= 1 min	Runoff Volume	= 866 cum
Drainage Area	= 2.76 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 9.24 min
Basin Slope	= 0.3 %	Hydraulic Length	= 166.7 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

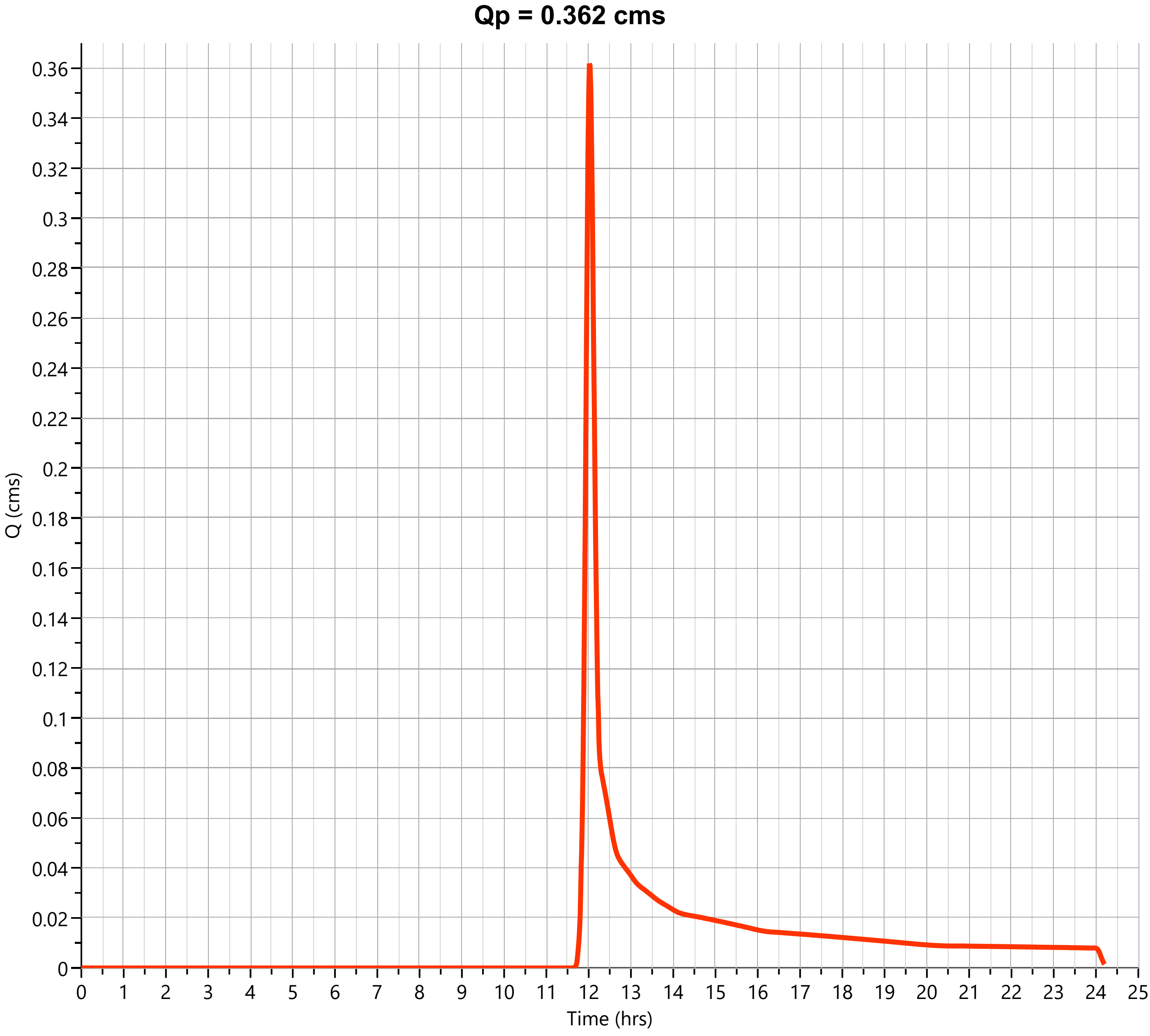


Hydrograph Report

6A

Hyd. No. 11

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.3618 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.02 hrs
Time Interval	= 1 min	Runoff Volume	= 1,016 cum
Drainage Area	= 3.18 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 11.66 min
Basin Slope	= 0.06 %	Hydraulic Length	= 100.95 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

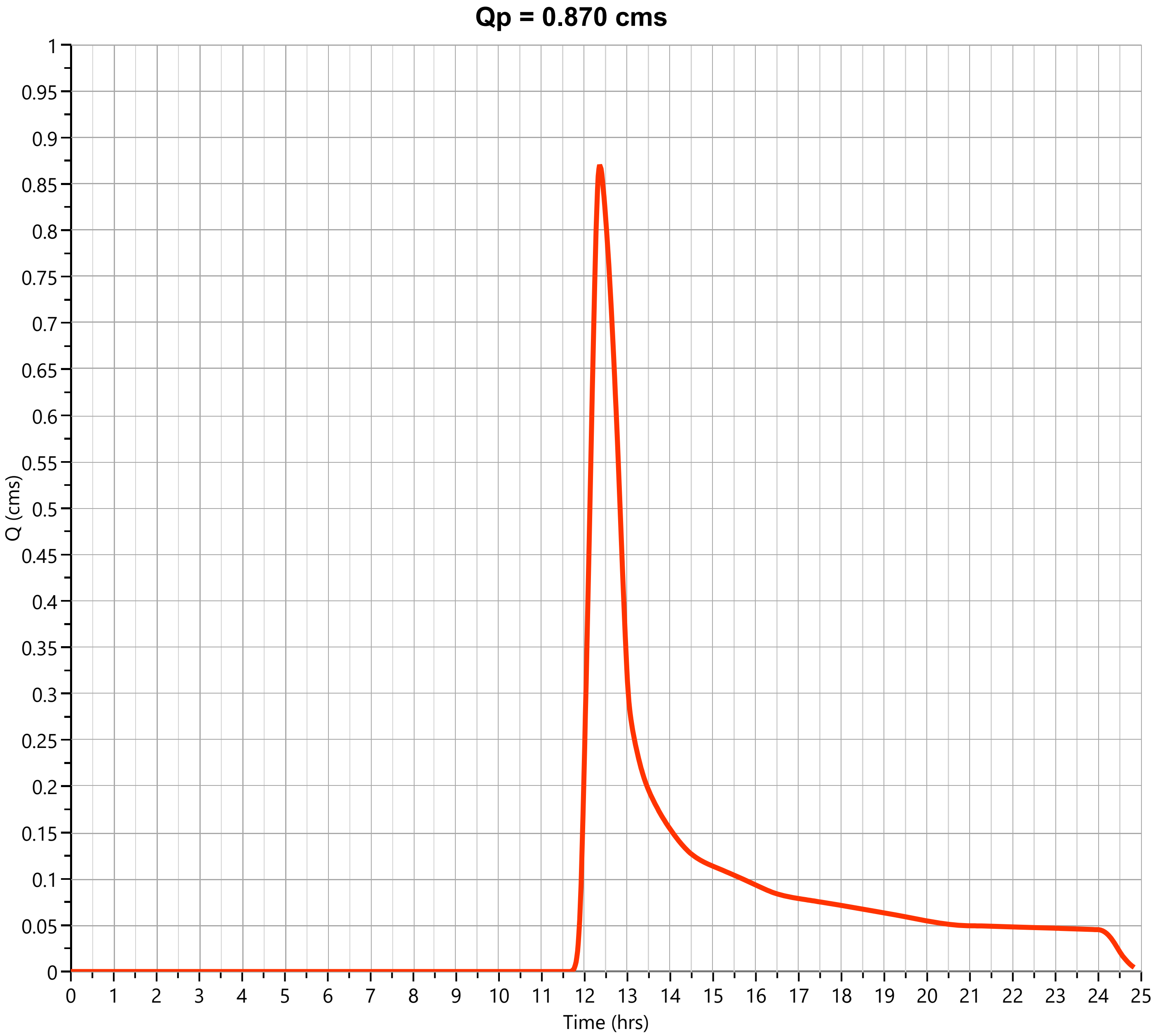


Hydrograph Report

7A

Hyd. No. 12

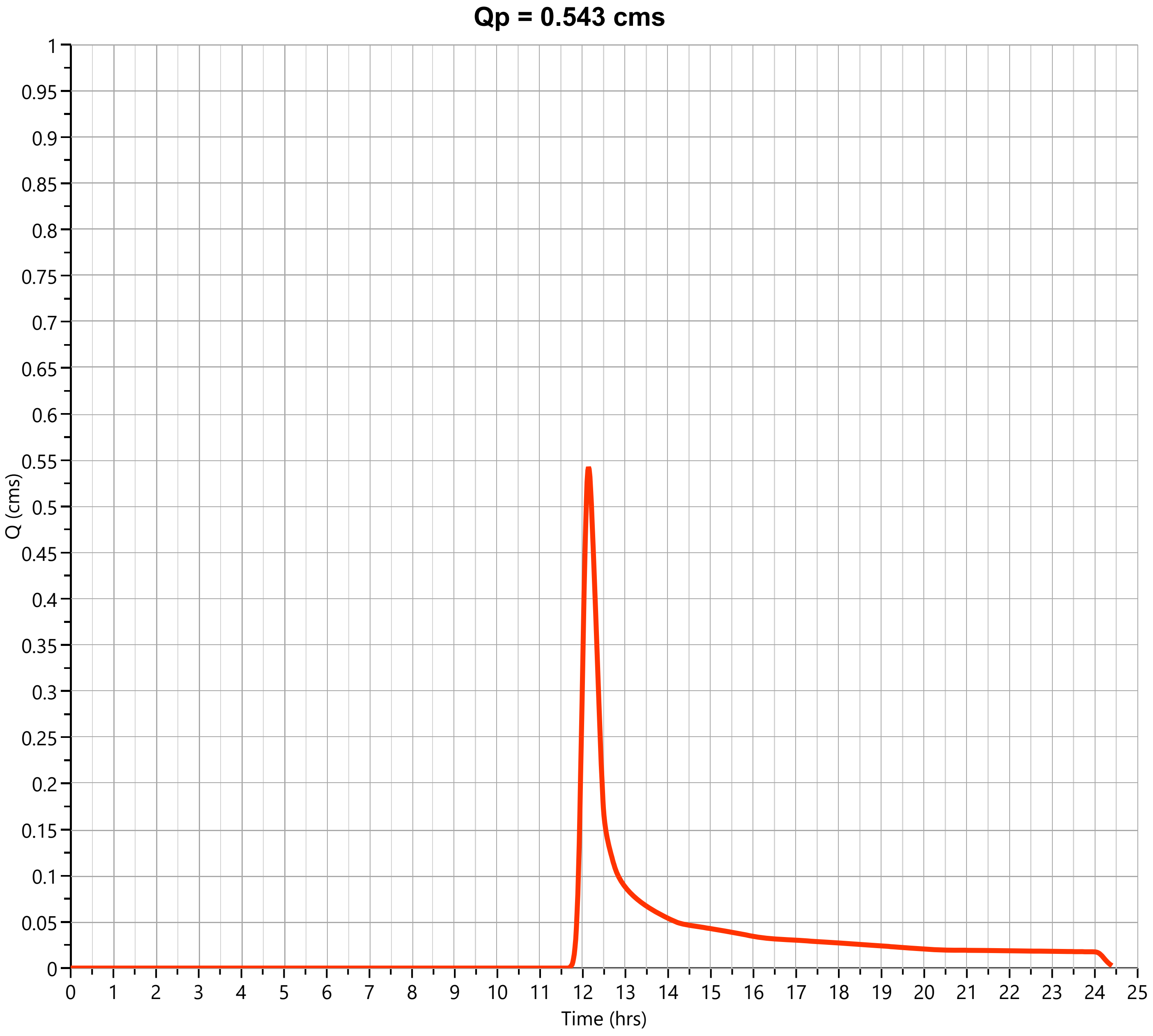
Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.8705 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.35 hrs
Time Interval	= 1 min	Runoff Volume	= 5,703 cum
Drainage Area	= 18.08 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 40.78 min
Basin Slope	= 0.04 %	Hydraulic Length	= 418.85 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208



8A

Hyd. No. 13

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.5427 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.13 hrs
Time Interval	= 1 min	Runoff Volume	= 2,231 cum
Drainage Area	= 7.04 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 20.9 min
Basin Slope	= 0.17 %	Hydraulic Length	= 362.46 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208



Hydrograph Report

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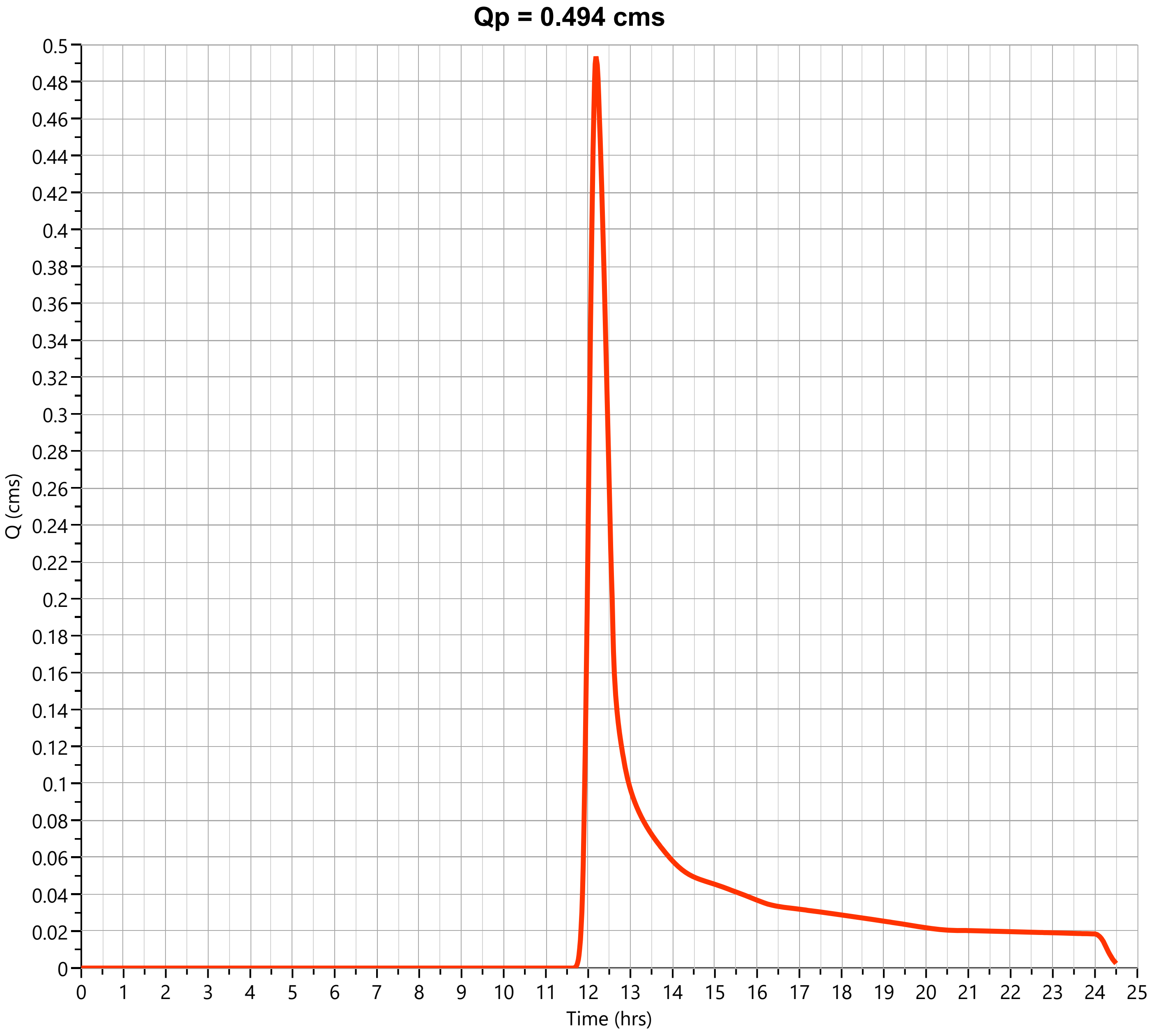
08-25-2022

8B

Hyd. No. 14

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.4936 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.18 hrs
Time Interval	= 1 min	Runoff Volume	= 2,347 cum
Drainage Area	= 7.42 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 25.48 min
Basin Slope	= 0.13 %	Hydraulic Length	= 409.81 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208



Hydrograph Report

Project Name:

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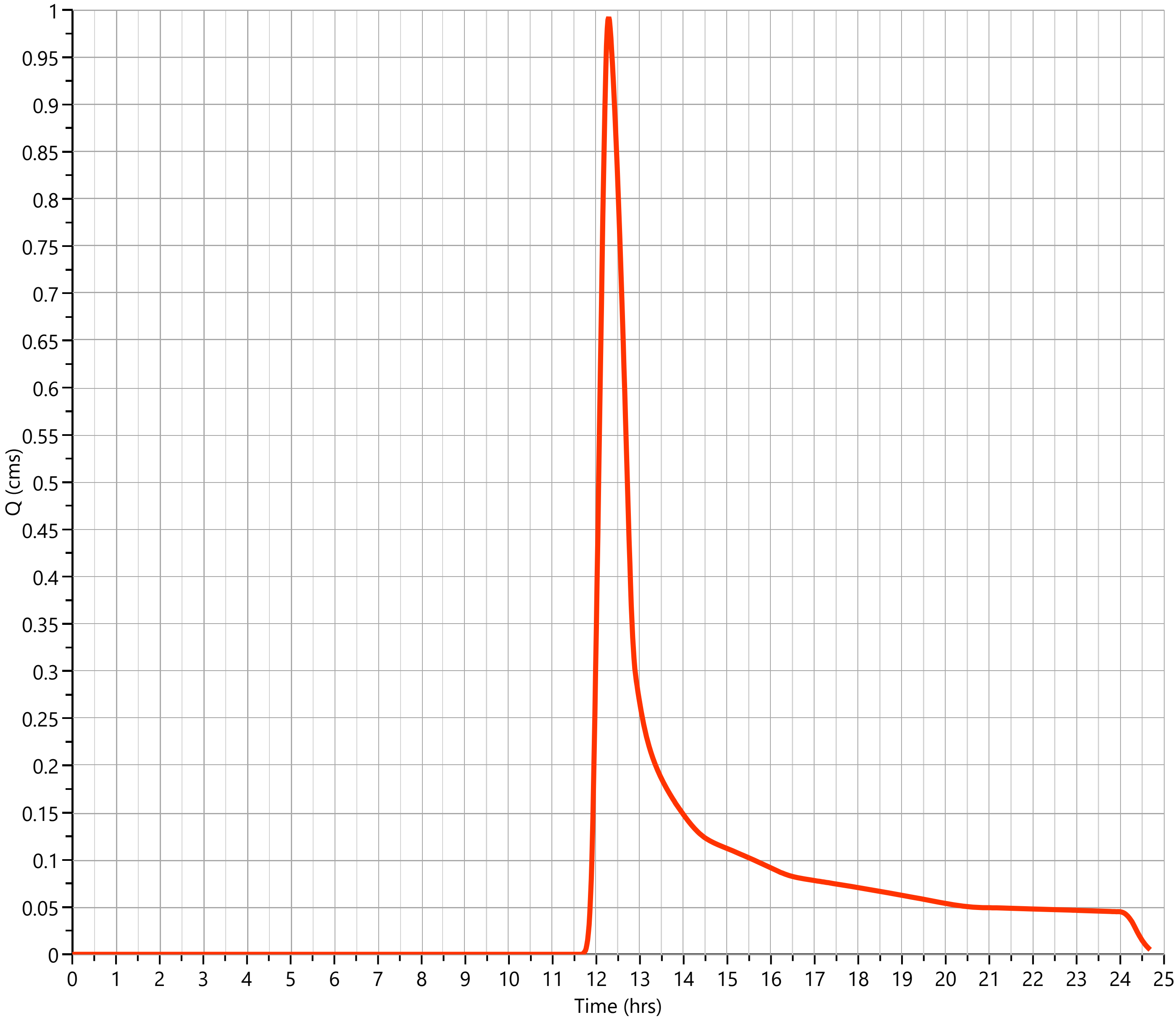
9A

Hyd. No. 15

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.9925 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.28 hrs
Time Interval	= 1 min	Runoff Volume	= 5,700 cum
Drainage Area	= 18.16 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 35.52 min
Basin Slope	= 0.15 %	Hydraulic Length	= 677.73 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

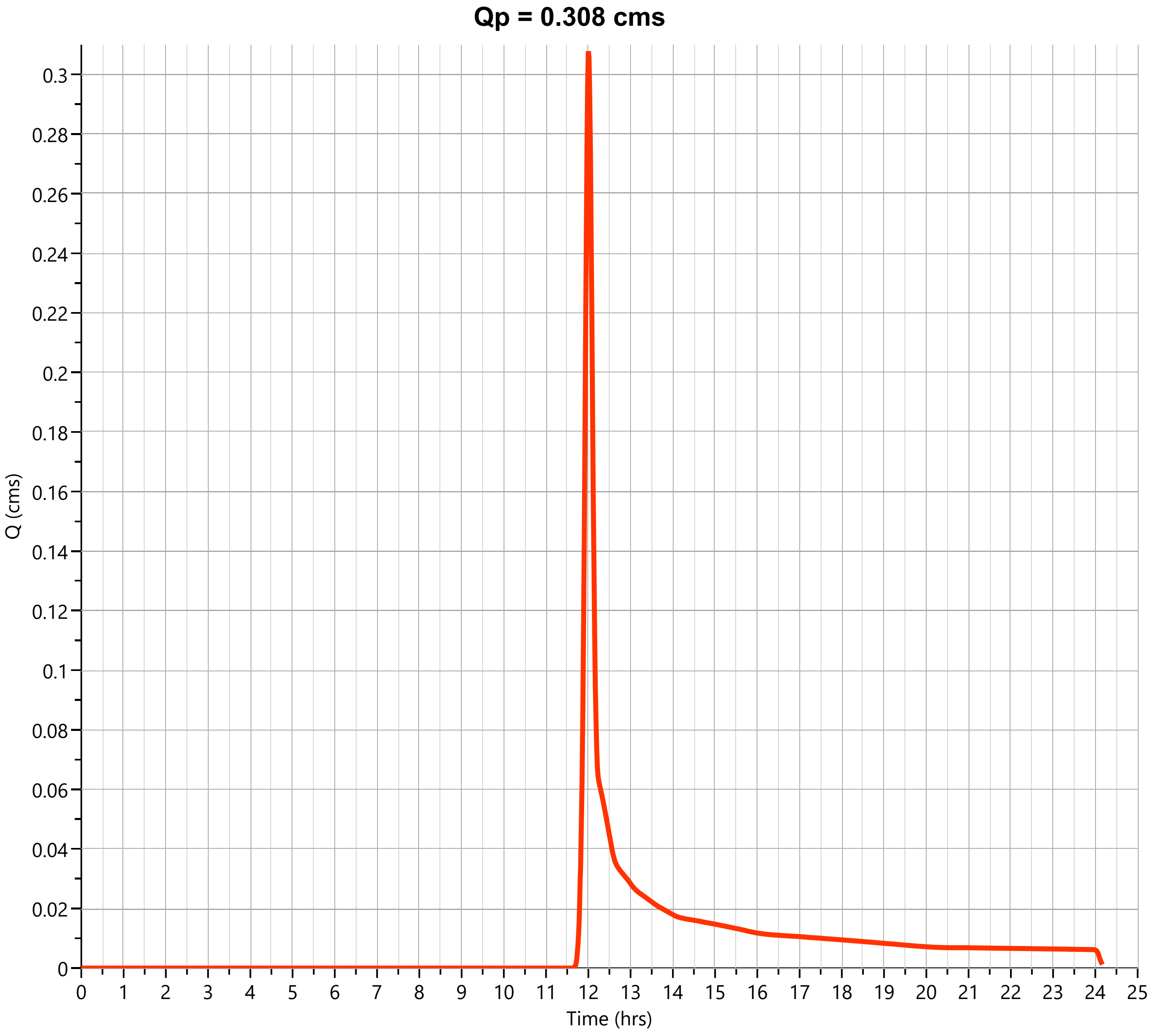
Qp = 0.993 cms



10A

Hyd. No. 16

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.3078 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.00 hrs
Time Interval	= 1 min	Runoff Volume	= 791 cum
Drainage Area	= 2.52 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 10.03 min
Basin Slope	= 0.23 %	Hydraulic Length	= 162.42 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

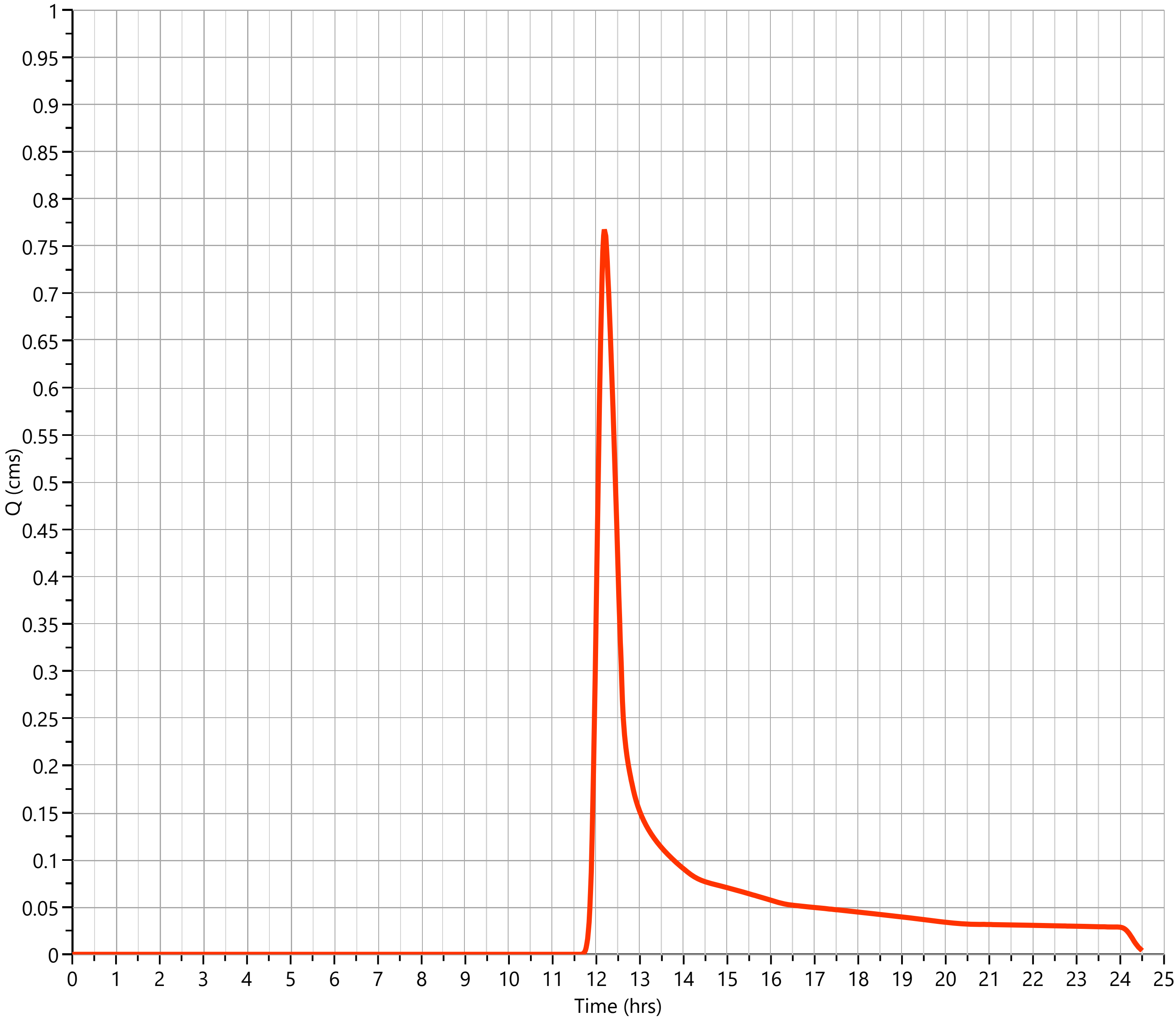


11A

Hyd. No. 17

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.7677 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.18 hrs
Time Interval	= 1 min	Runoff Volume	= 3,650 cum
Drainage Area	= 11.54 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 26.81 min
Basin Slope	= 0.06 %	Hydraulic Length	= 297.45 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

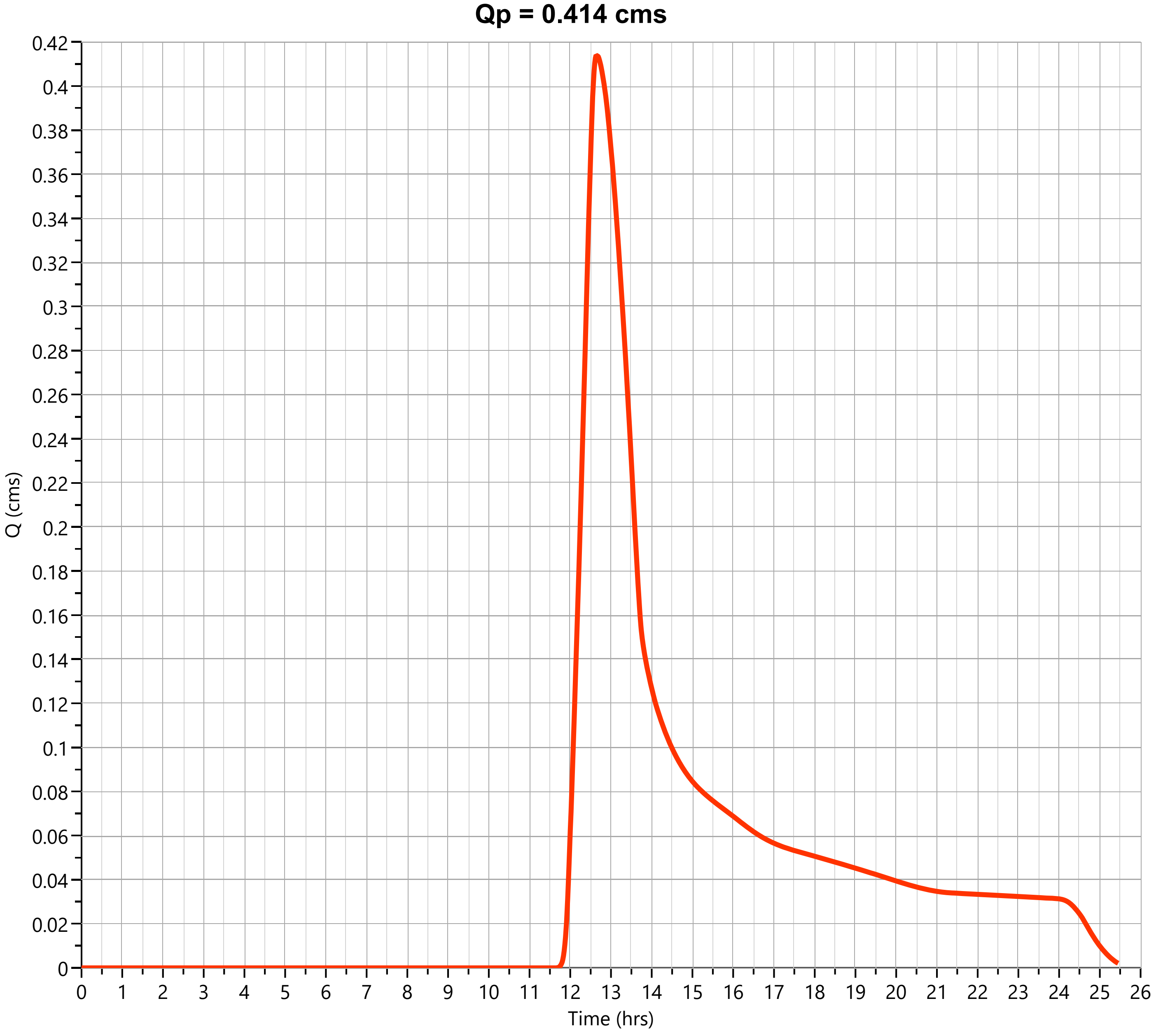
Qp = 0.768 cms



12A

Hyd. No. 18

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.4143 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.65 hrs
Time Interval	= 1 min	Runoff Volume	= 3,915 cum
Drainage Area	= 12.4 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 69.28 min
Basin Slope	= 0.01 %	Hydraulic Length	= 416.74 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

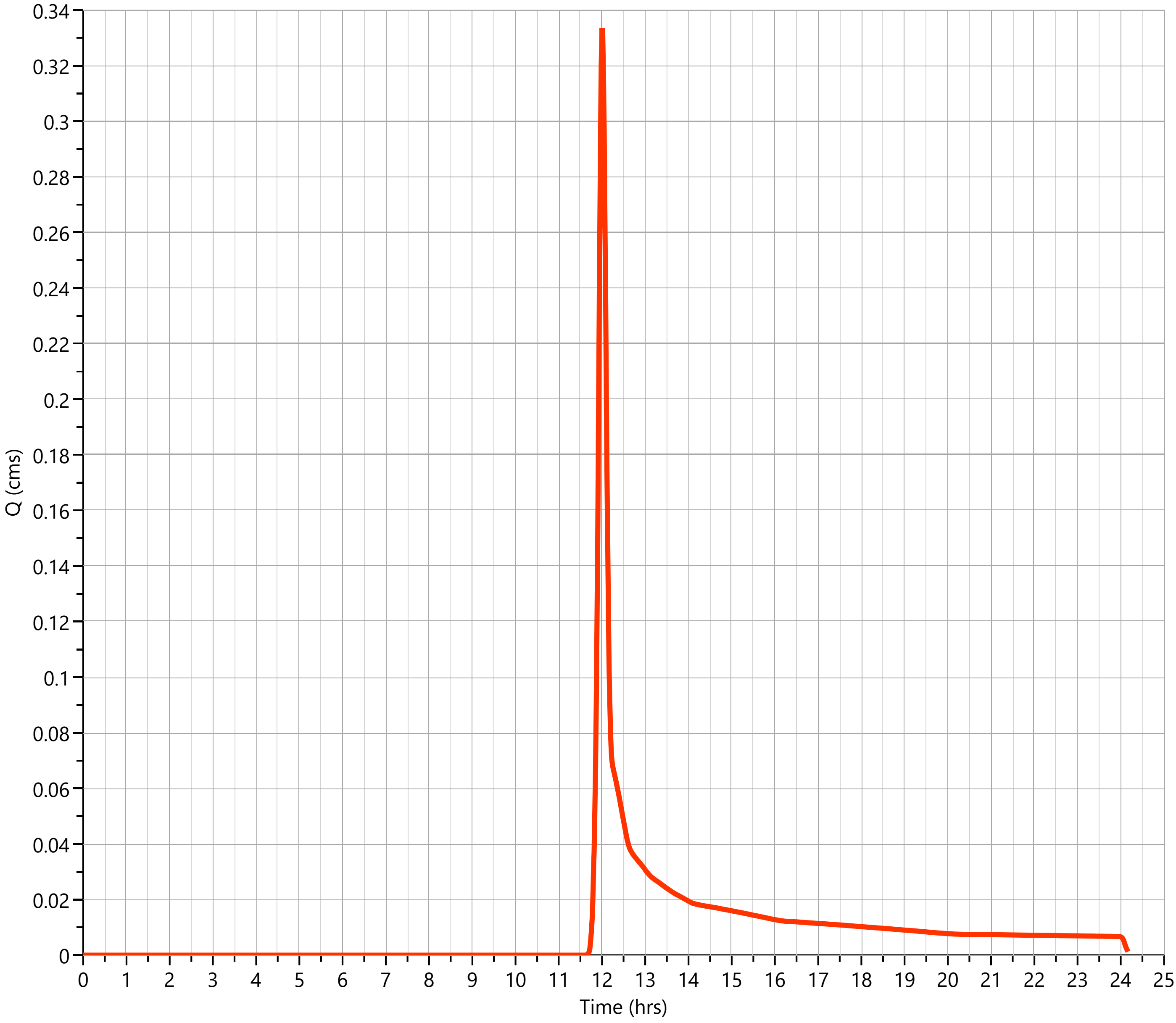


12B

Hyd. No. 19

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.3335 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.00 hrs
Time Interval	= 1 min	Runoff Volume	= 857 cum
Drainage Area	= 2.73 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 9.35 min
Basin Slope	= 0.37 %	Hydraulic Length	= 188.01 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

Qp = 0.333 cms



Hydrograph Report

Project Name:

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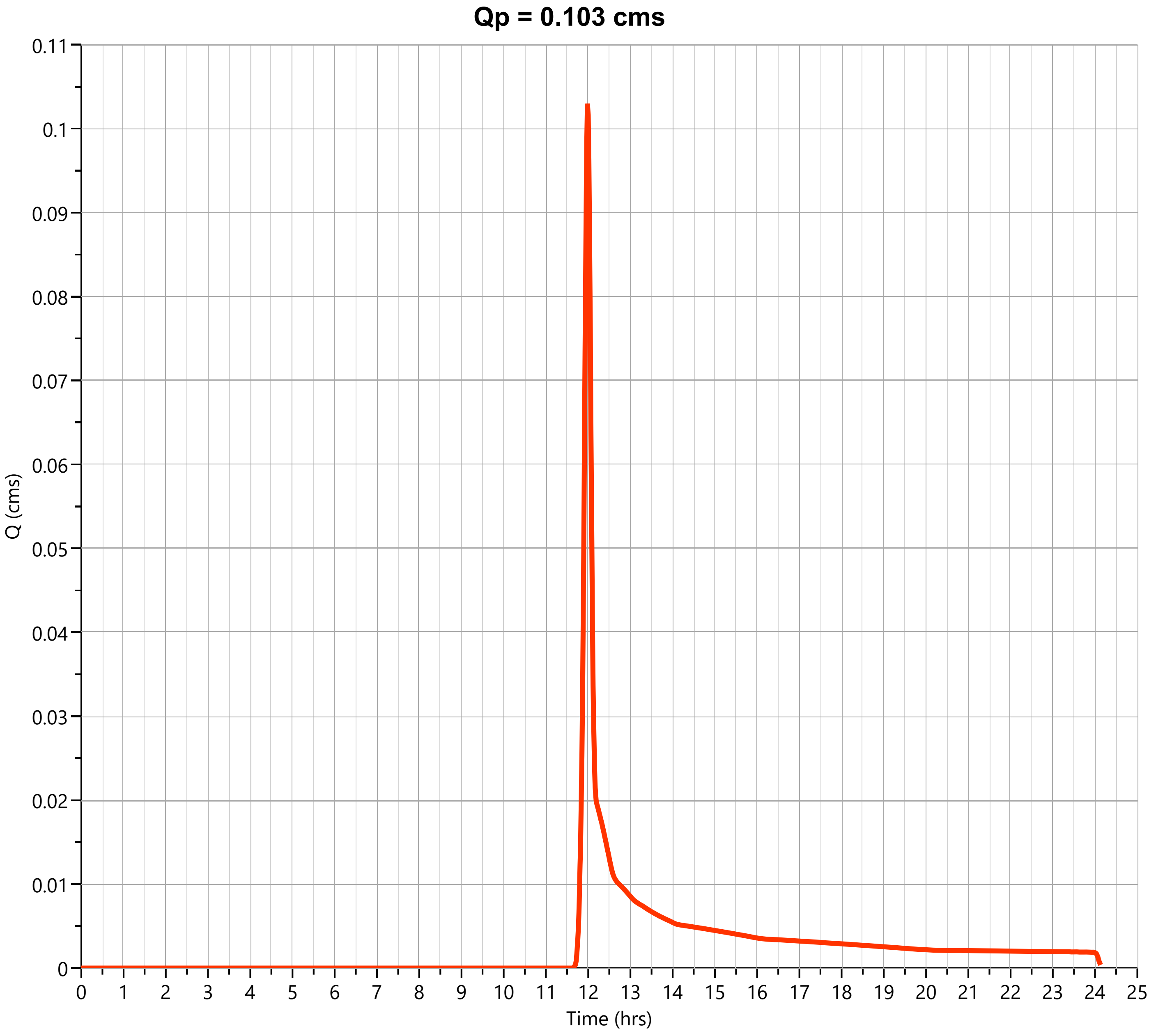
13A

Hyd. No. 20

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.1030 cms
Storm Frequency	= 10-yr	Time to Peak	= 11.98 hrs
Time Interval	= 1 min	Runoff Volume	= 242 cum
Drainage Area	= 0.79 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 7.11 min
Basin Slope	= 0.29 %	Hydraulic Length	= 116.59 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

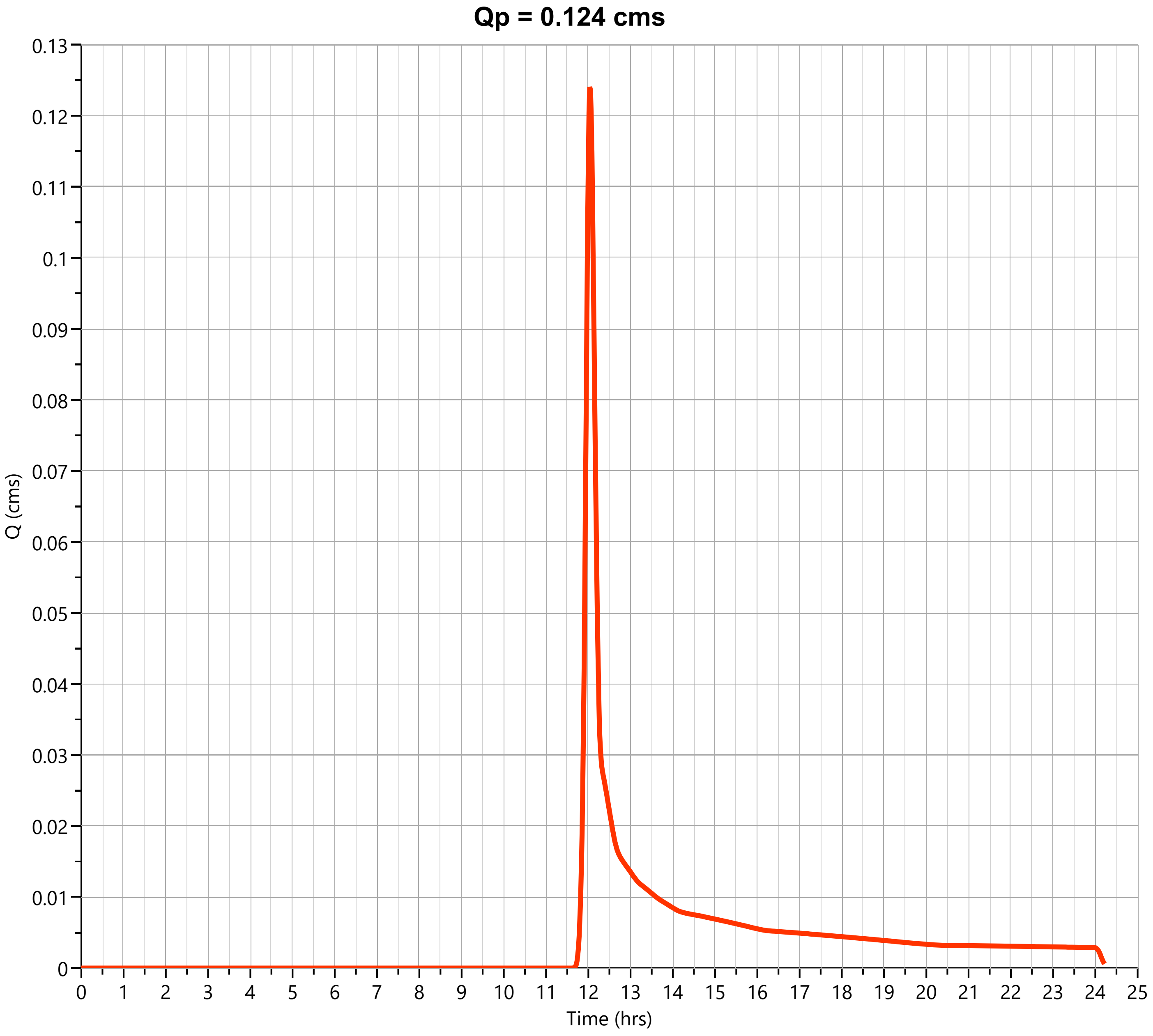


Hydrograph Report

13B

Hyd. No. 21

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.1240 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.03 hrs
Time Interval	= 1 min	Runoff Volume	= 368 cum
Drainage Area	= 1.19 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 13.3 min
Basin Slope	= 0.17 %	Hydraulic Length	= 201.56 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208



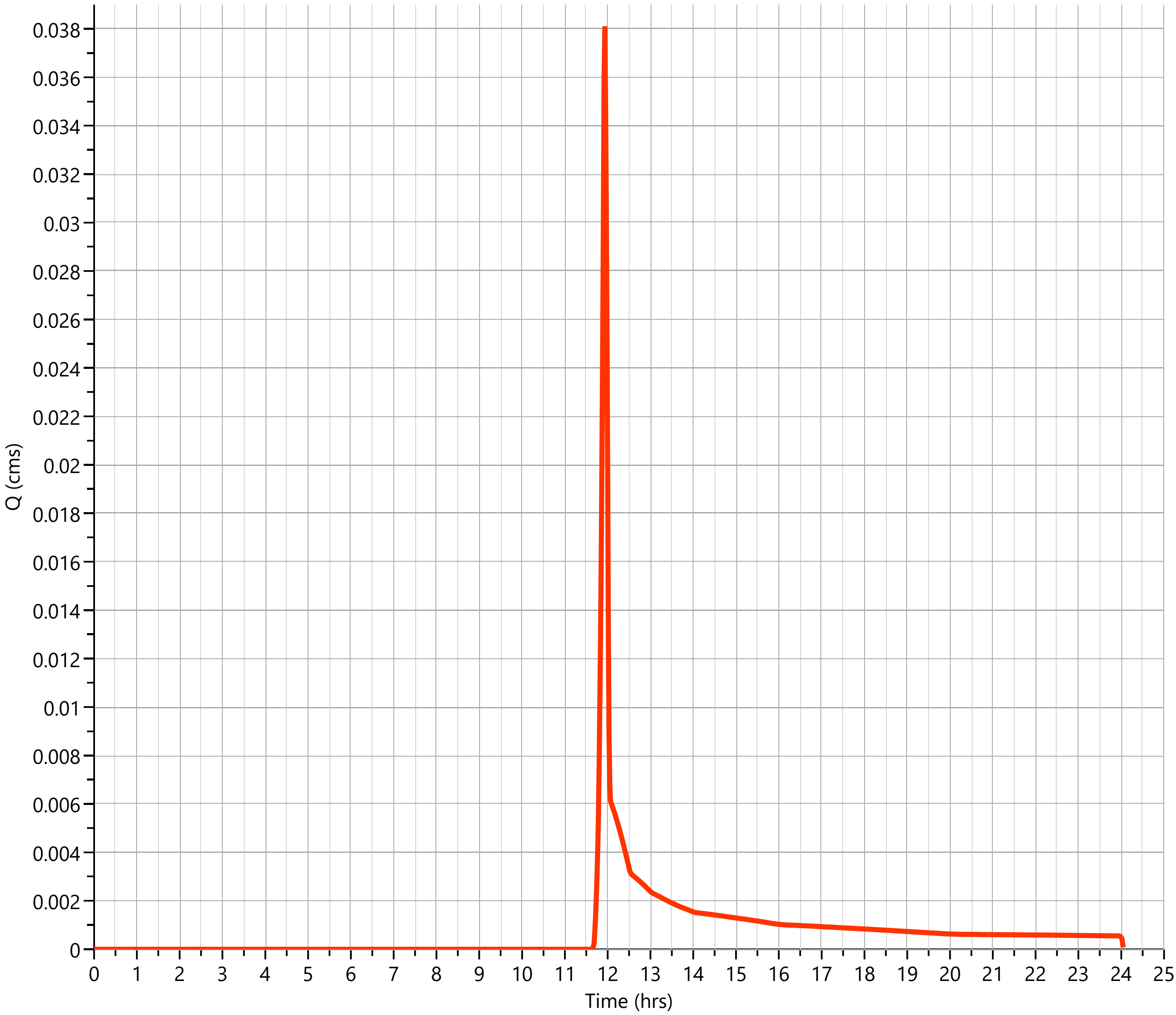
Hydrograph Report

13C

Hyd. No. 22

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.0381 cms
Storm Frequency	= 10-yr	Time to Peak	= 11.93 hrs
Time Interval	= 1 min	Runoff Volume	= 70.6 cum
Drainage Area	= 0.24 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 1.57 min
Basin Slope	= 1.14 %	Hydraulic Length	= 32.49 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

Qp = 0.038 cms



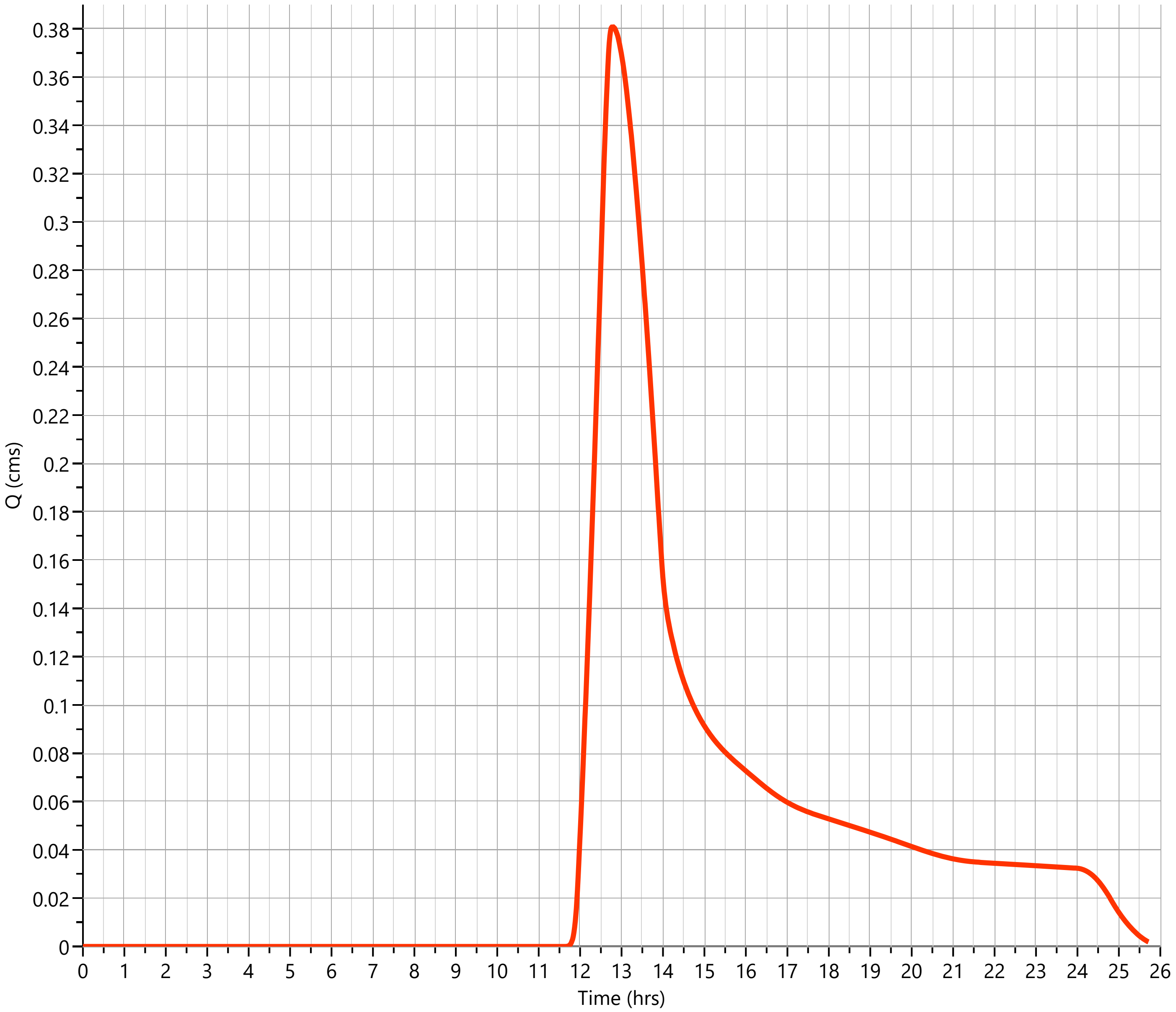
Hydrograph Report

13D

Hyd. No. 23

Hydrograph Type	= NRCS Runoff	Peak Flow	= 0.3810 cms
Storm Frequency	= 10-yr	Time to Peak	= 12.78 hrs
Time Interval	= 1 min	Runoff Volume	= 4,027 cum
Drainage Area	= 12.83 ha	Curve Number	= 49
Tc Method	= Kirpich	Time of Conc. (Tc)	= 80.34 min
Basin Slope	= 0.01 %	Hydraulic Length	= 505.18 m
Total Rainfall	= 161 mm	Design Storm	= Type II
Storm Duration	= 24 hrs	Shape Factor	= 0.208

Qp = 0.381 cms



Design Storm Report

Storm Distribution: NRCS/SCS - Type II, 24-hr

Storm Duration	**Total Rainfall Volume (mm)**							
	1-yr	**2-yr**	**3-yr**	**5-yr**	**✓ 10-yr**	**25-yr**	**50-yr**	**100-yr**	
24 hrs	0.000	98.247	0.000	136.061	161.098	192.731	216.198	239.492	

Incremental Rainfall Distribution, 10-yr

Time (hrs)	Precip (mm)	Time (hrs)	Precip (mm)	Time (hrs)	Precip (mm)	Time (hrs)	Precip (mm)	Time (hrs)	Precip (mm)
11.42	0.299	11.60	0.905	11.78	2.354	11.97	2.217	12.15	0.453
11.43	0.303	11.62	1.011	11.80	2.648	11.98	1.546	12.17	0.443
11.45	0.307	11.63	1.117	11.82	2.943	12.00	0.875	12.18	0.433
11.47	0.311	11.65	1.223	11.83	3.238	12.02	0.553	12.20	0.422
11.48	0.316	11.67	1.329	11.85	3.533	12.03	0.524	12.22	0.412
11.50	0.320	11.68	1.435	11.87	3.827	12.05	0.514	12.23	0.402
11.52	0.376	11.70	1.541	11.88	4.122	12.07	0.504	12.25	0.392
11.53	0.481	11.72	1.647	11.90	4.417	12.08	0.494	12.27	0.382
11.55	0.587	11.73	1.753	**11.92**	**4.712**	12.10	0.484	12.28	0.371
11.57	0.693	11.75	1.859	11.93	3.081	12.12	0.473	12.30	0.361
11.58	0.799	11.77	2.043	11.95	2.887	12.13	0.463	12.32	0.351