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STUDY AND DESIGN OF DRAINAGE STRUCTURE AND ITS CHARACTERISTICS ALONG N-CHOE IN CHANDIGARH REGION

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ABSTRACT

The study focuses on the design and analysis of drainage structures along the N-Choe in the Chandigarh region, addressing issues related to flooding, drainage, and sedimentation. The project commenced with an extensive literature review to understand the existing conditions and previous studies on similar drainage systems. Detailed topographical surveys were conducted using Differential Global Positioning System (DGPS) and Total Station (TS) equipment to capture accurate site data. Additionally, soil investigation was carried out using various geotechnical methods, including Dynamic Cone Penetrometer Test (DCPT), Standard Penetration Test (SPT), and manual auger drilling. A total of 12 boreholes were drilled along the Choe at intervals of 500 to 700 meters, reaching a maximum depth of 5 meters. The data obtained from these investigations were analysed, followed by the preparation of

detailed engineering drawings. Based on the findings, a series of remedial measures were proposed, including improvements in the drainage system and the redesign of the channel to better manage water flow and reduce flooding risks. The proposed solutions aim to enhance the overall effectiveness of the drainage infrastructure in the region.

Keywords: N-Choe, flooding, topographical survey, DGPS, Total Station, soil investigation, DCPT, SPT, auger tool, channel redesign, remedial measures and water flow management.

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1. INTRODUCTION

Urban flooding and poor water drainage systems remain significant challenges for cities worldwide, particularly those undergoing rapid urbanization and infrastructure development. Chandigarh, a city known for its planned layout, faces frequent waterlogging, localized flooding, and ineffective drainage, especially during the monsoon season. These issues are exacerbated by factors such as inadequate stormwater management infrastructure, the urban heat island effect, increasing impervious surfaces, and erratic rainfall patterns attributed to climate change. A key watercourse that plays a vital role in managing stormwater runoff in the region is the **N-Choe**, a seasonal drain that helps channel excess rainwater away from urbanized areas. However, the current state of the N-Choe, characterized by poor maintenance, siltation, and inefficient alignment, often fails to effectively mitigate flood risks.

The present study focuses on structural investigation aimed at strengthening and optimizing the N-Choe's ability to reduce flooding and improve water drainage in Chandigarh. Specifically, this research seeks to explore remedial measures for the structural and functional improvement of the N-Choe, including the realignment, levelling, and reinforcement of embankments, as well as the maintenance of bridges crossing the watercourse. By following a proper procedure (as shown below in Figure1), this thesis aims to assess and recommend practical solutions to these challenges, with the ultimate goal of improving the N-Choe's role in flood mitigation and sustainable water management.

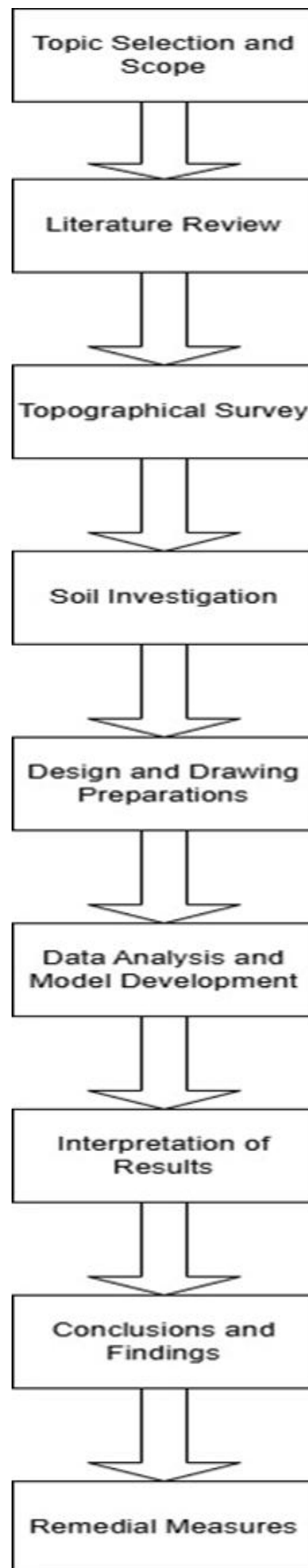


Figure1: Flowchart showing the Research Process

Several studies have previously examined the challenges and proposed solutions for urban water management and flood control worldwide. Notably, Ravnish Kaur (2022) explored the hydrological and hydraulic modelling of urban drainage systems, emphasizing the importance of accurate simulations in urban water management. Webber and Fletcher (2022) provided innovative strategies for sustainable stormwater drainage, focusing on green infrastructure solutions that integrate ecological principles into urban planning. Similarly, Wang (2020) highlighted the role of smart technology in optimizing drainage networks, emphasizing real-time monitoring and adaptive management strategies to cope with climate change-induced rainfall patterns.

Huang and Rahman (2021) contributed to the advancement of structural materials used in drainage systems, discussing the potential of advanced composites to improve the durability and efficiency of drainage channels. Qi (2020) delved into the integration of climate-resilient design features in drainage infrastructure, proposing methods to enhance the capacity of drainage systems to handle extreme weather events via Nature – Based Solutions (NBS) like Sponge City Program (SCP) (whose principle and concept is discussed below in Figure2). Lastly, Steis Thorsby (2020) examined the role of community-based approaches in drainage system design, arguing that stakeholder involvement is crucial in ensuring both functionality and social acceptance of drainage projects.

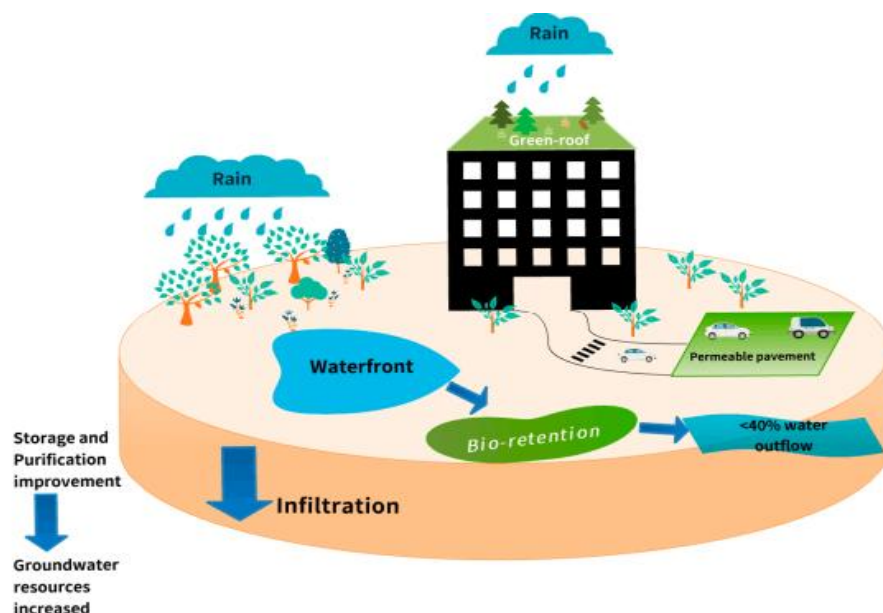


Figure2: Sponge City Program (SCP) principle and concept (Qi et al.2020)

Building on these insights, this study proposes a structural investigation of the N-Choe's alignment, embankment conditions, bridge design, and de-silting processes in Chandigarh. By evaluating the feasibility of various interventions, this study aims to contribute valuable knowledge to the field of urban water management and provide actionable recommendations for improving the performance of the N-Choe in the Chandigarh region.

2. N-CHOE: AN OVERVIEW

N-Choe (as shown below in Figure3) refers to a traditional stream or seasonal river system found in the Chandigarh region, particularly within the broader context of the Punjab region. In the local dialect and usage, a "Choe" is typically a seasonal rivulet or a small stream, which is a crucial component of the region's natural drainage system. These rivulets or streams tend to flow during the monsoon season but may dry up during the dry months.

In the Chandigarh region, the term "N-Choe" could specifically be referring to one of the small but important seasonal streams that flow across the urban landscape. The N-Choe might not be a major river or perennial stream but plays a significant role in the hydrology of the region, especially in terms of water runoff, groundwater recharge, and seasonal watercourses.



Figure3: N-Choe

3. PATH OF N-CHOE

N-Choe's route is described and depicted in the form of a map below.in Figure4:

Chandigarh: The Punjab Civil Secretariat is located opposite to Sector 1, Chandigarh, where the N-Choe starts. Then it goes by the Bougainvillea Park in Sector 3, the Leisure Valley Park in Sector 10, and the Rose Garden and Shanti Kunj Garden in Sector 16. Finally, before

reaching a connection in Sector 52 at the Kajheri hamlet and Sector 51 near Burail Jail, it passes via Sectors 23, 36, 42, and 53.

Mohali: From sector 51 of Chandigarh, the N Choe passes through sectors 62, 63, Phase 9, 67, and 81 on its way to Mohali, where it reaches the village of Chilla Manauli. The creek then flows towards Patiala district before entering the Ghaggar River in Haryana.

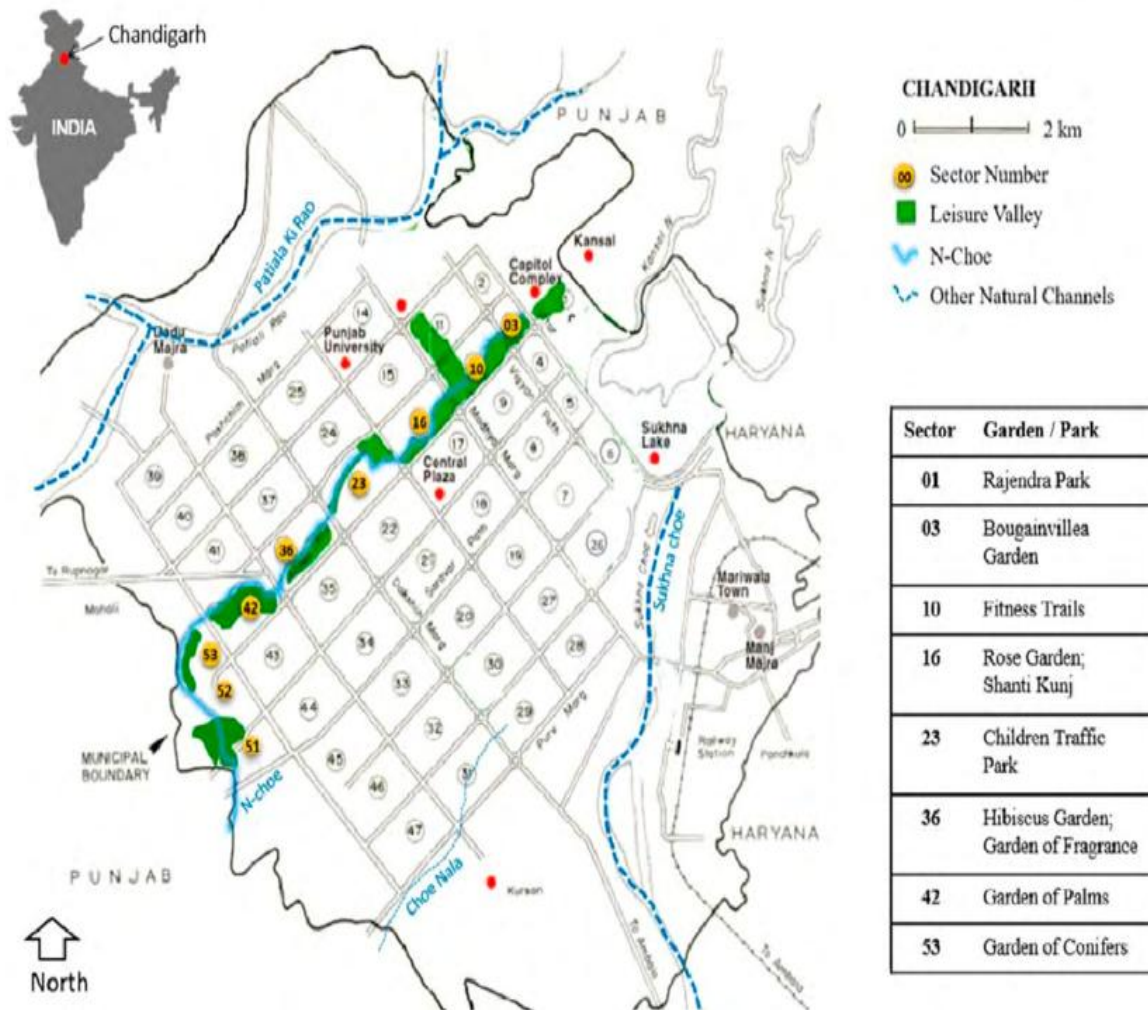


Figure4: Map showing path of N-Choe

4. RESEARCH METHODOLOGY

The steps that are followed while doing the study are discussed below in detail:

Topographical Survey

Objective: To map the N-Choe area and understand the topography, slope, and drainage characteristics for effective flood mitigation strategies.

Tools/Methods Used: Total Station (TS), Differential Global Positioning System (DGPS).

1. Pre-Survey Preparation

- Define survey boundary and study area based on N-Choe region.
- Collect historical maps and satellite images to understand the existing drainage patterns.
- Acquire permissions from local authorities for survey work.

2. Data Collection Using Total Station

- Set up Total Station at strategic points for precise angle and distance measurements.
- Perform detailed surveying of the study area including terrain features, elevations, water bodies, roads, and infrastructures.
- Record coordinates, elevations, and other critical features necessary for topographic analysis.

3. Data Collection Using DGPS

- Use DGPS for accurate positioning and elevation data, particularly in areas with high water movement or difficult access but have a good satellite network.
- Integrate DGPS data with Total Station data for higher precision in mapping.

4. Mapping & Preliminary Analysis

- Generate contour maps, slope analysis, and elevation profiles from the collected data.
- Identify flood-prone areas and analyse the flow direction of the N-Choe.
- Calculate the drainage capacity of the area to determine problem zones.

Soil Investigation

Objective: To investigate the soil characteristics along the N-Choe region, which will aid in the design of flood mitigation and drainage systems.

Tools/Methods Used: Auger, DCPT (Dynamic Cone Penetrometer Test), SPT (Standard Penetration Test).

1. Site Selection for Boreholes:

- Identify 12 key locations along the N-Choe region for soil investigation.
- Choose borehole sites based on flood risk zones, drainage needs, and proximity to water flow.

2. Borehole Drilling and Soil Sampling (12 Boreholes):

- Perform borehole drilling at selected locations using a hand auger or mechanical auger.
- Drill boreholes up to a maximum depth of 5 meters to assess subsurface conditions.

- Collect soil samples at various depths (e.g., 0–1m, 1–2m, 2–3m, etc.) for laboratory analysis.

3. Dynamic Cone Penetrometer Test (DCPT):

- Conduct DCPT at selected locations to assess soil compaction and bearing capacity.
- Measure the penetration resistance of soils and analyse the results to evaluate soil strength and drainage suitability.

4. Standard Penetration Test (SPT):

- Perform SPT at various depths within the boreholes to evaluate soil density and consistency.
- Record N-values to determine soil's resistance to penetration, which helps assess its potential for liquefaction and bearing capacity.

5. Laboratory Analysis:

- Analyse soil samples for grain size distribution, moisture content, permeability, and shear strength.
- Conduct tests to determine soil infiltration rates, drainage properties, and suitability for flood mitigation measures.
- Assess soil compaction and its impact on the potential effectiveness of stormwater management systems.

Drawing Preparation and Design

Objective: To create detailed drawings and designs for the proposed flood mitigation and drainage solutions based on topographic and soil investigation data.

Tools/Methods Used: AutoCAD.

1. Design Parameters Definition:

- Define key design parameters based on topographic survey and soil analysis data (e.g., rainfall intensity, drainage capacity, soil permeability, flood-prone areas).
- Identify types of flood mitigation measures required, such as stormwater drains, retention basins, and diversion channels.

2. Preliminary Design Concept Development:

- Develop preliminary design layouts for the proposed flood mitigation system, incorporating drainage channels, retention basins, and water diversion structures.
- Consider existing infrastructure, natural terrain features, and potential environmental impacts in the design process.

3. Detailed Design and Drawing Preparation:

- Create detailed design drawings using AutoCAD, including profiles, cross-sections, and layout plans.
- Specify materials, dimensions, construction methods, and operational parameters for each drainage system component.

4. Design Review and Refinement:

- Review the design drawings for feasibility, practicality, and compliance with local standards and regulations.
- Adjust the designs based on feedback from supervisors, peers, and local authorities.
- Ensure the designs integrate well with the topography and soil conditions.

Data Analysis for Flood Mitigation and Drainage Optimization

Objective: To analyse the data collected through topographical surveys to assess the performance of existing N-Choe channel.

Tools/Methods Used: Rational method, Manning's equation and Continuity equation.

1. **Rational method:** The Rational Method is a widely used approach for estimating peak discharge in small drainage areas, particularly in urban settings. It is especially useful for designing stormwater infrastructure such as culverts, storm drains, and detention basins.
2. **Manning's equation:** Manning's equation is an empirical formula used to estimate the average velocity of water flow in open channels, such as rivers, streams, and irrigation ditches. It is widely applied in hydrology and civil engineering for designing and analysing open channel flow systems.

The equation is expressed as:

$$V = \frac{1}{n} * R^{0.67} * S^{0.5}$$

Where:

- V = Average velocity of flow (m/s)
 - n = Manning's roughness coefficient (dimensionless)
 - R = Hydraulic radius (m), calculated as the cross-sectional area of flow (A) divided by the wetted perimeter (P).
 - S = Channel slope (dimensionless), typically the slope of the energy grade line or the channel bed slope.
3. **Continuity equation:** The Continuity equation is a fundamental principle in fluid mechanics that expresses the conservation of mass in a flowing fluid. In the context

of open channel flow, it relates the flow rate (discharge) to the cross-sectional area and the flow velocity.

For steady, incompressible flow, the Continuity Equation is:

$$Q=A \times V$$

Where:

- Q = Discharge (m^3/s)
- A = Cross-sectional area of flow (m^2)
- V = Average velocity of flow (m/s)

Analysis of Data

The data analysis commenced with the estimation of discharge entering the N-Choe using the Rational Method, incorporating rainfall intensity, catchment area, and runoff coefficient. Subsequently, the existing discharge carrying capacity of the N-Choe was evaluated utilizing Manning's equation, applying topographical survey data to assess the channel's ability to convey peak flows. Based on these analyses, a new cross-sectional design was proposed to ensure the N-Choe can accommodate the design discharge effectively.

1. Estimation of discharge from the catchment area along N-Choe:

The Rational method is used to estimate the discharge from the catchment along the Choe. It states that:

$$Q_p = C \cdot P_c \cdot A, \text{ where}$$

$$Q_p = \text{Peak rate of runoff in } \text{m}^3/\text{s}$$

$$C = \text{Runoff coefficient} = 0.435$$

$$P_c = \text{Critical rainfall intensity in m/s}$$

$$A = \text{Catchment area in } \text{m}^2$$

$$\text{Critical rainfall intensity } (P_c) = 2P_0 / (1 + T_c), \text{ where } P_0 = \text{maximum rainfall intensity in m/s}$$

$$T_c = \text{Time of concentration in hrs} = T_i + T_f, \text{ where } T_i = \text{Inlet time in hrs.}$$

$$T_f = \text{Flow time in hrs.}$$

$$T_i = (0.885 \cdot L^3 / H)^{0.385}, \text{ where } L = \text{Length of flow in km from critical point to drain}$$

$$H = \text{Total fall of level in m from critical point to drain}$$

$$T_f = \text{Length of drain / Velocity in the drain}$$

The detailed calculations are shown in Table 1.

Table 1: Calculation for design discharge in N-Choe for different Sections:				
C= Run off coefficient adopted	=	0.435		
Minimum slope taken	=	1	in	4000
Path length of Distance of farthest point to mouth of drain = L	=	500	m	
Total Fall of Level = H	=	0.125	m	
Ti = Inlet Time in hours = $(0.885 \cdot L^3 / H)^{0.385}$	=	0.95	hrs	
Length of the drain	=	13	km	
Maximum Velocity in the drain taken	=	3	m/s	
Channel flow time Tf = length of the drain/ Velocity in the drain	=	1.204	hrs	
Tc = Tf + Ti	=	2.158	hrs	
Maximum rainfall intensity Po taken	=	20	mm/hr	
Critical rainfall intensity $P_c = P_o \cdot (2 / (1 + T_c))$	=	12.667	mm/hr	
	=	0.000003519	m/sec	
$Q = C \cdot P_c \cdot A$				

S. No.	Chainage (m)	Sector No.	Full/Half	Catchment Area (A) (km ²)	Q (m ³ /s)	Cumulative Q (m ³ /s)
1	0-750	2	0.5	0.4	0.30612	1.06
		3	0.5	0.49	0.375	
		4	0.5	0.49	0.375	
2	750-2430	9	1	1.54	2.35716	7.79
		10	1	1.52	2.32655	
		11	1	1.34	2.05103	
3	2430-4230	14	1	2.38	3.64288	17.10
		15	1	1.45	2.2194	
		16	1	1.52	2.32655	
		18	0.5	1.46	1.11735	
4	4230-6420	22	0.5	1.62	1.2398	24.73
		23	0.5	1.6	1.2245	
		24	1	1.26	1.92858	
		25	1	1.41	2.15818	
		west of 25	1	0.71	1.08674	
5	6420-7980	35	0.5	1.62	1.2398	38.66
		36	1	1.46	2.23471	
		37	1	1.45	2.2194	
		38	1	2.23	3.41329	
		west 38	1	1.15	1.76022	
		Dadu Majra	1	2	3.06124	

6	7980-9600	39	1	1.48	2.26532	50.89
		40	1	2.93	4.48472	
		41	1	1.12	1.7143	
		42	0.5	1.8	1.37756	
		43	0.5	1.65	1.26276	
		45	0.5	1.46	1.11735	
7	9600-13000	50	0.5	1.48	1.13266	59.52
		51	0.5	1.3	0.9949	
		52	0.5	1.74	1.33164	
		53	1	0.73	1.11735	
		54	1	1.04	1.59185	
		55	1	1.07	1.63777	
		56	1	0.54	0.82654	

2. Estimation of discharge carrying capacity of the existing N-Choe channel:

The discharge carrying capacity of the existing N-Choe channel can be found out by using the Manning's equation, continuity equation and the cross-sectional drawings of the existing N-Choe for which data of topographical survey has been used.

The summary of calculations is shown below in Table 2.

❖ In the Table 2, a reference letter (P^*) has been used whose meaning is as follows:

For chainage 0m to 750m, Q should be more than $1.1\text{m}^3/\text{s}$.

For chainage 750m to 2430m, Q should be more than $8\text{m}^3/\text{s}$.

For chainage 2430m to 4230m, Q should be more than $17.2\text{m}^3/\text{s}$.

For chainage 4230m to 6420m, Q should be more than $25\text{m}^3/\text{s}$.

For chainage 6420m to 7980m, Q should be more than $39\text{m}^3/\text{s}$.

For chainage 7980m to 9600m, Q should be more than $51\text{m}^3/\text{s}$.

For chainage 9600m to 13000m, Q should be more than $60\text{m}^3/\text{s}$.

Table 2 - Summary of the calculations to estimate the discharge carrying capacity of the existing N-Choe channel

S.No.	Chainage (m)	Discharge, (Q), (m ³ /s)	“Ok” (if Q is as per P*), else “Not ok”
1	0		
2	30	5.52	Ok
3	60	3.01	Ok
4	90	4.82	Ok
5	120	4.71	Ok
6	150	13.85	Ok
7	180	31.39	Ok
8	210	25.78	Ok
9	240	13.50	Ok
10	270	29.66	Ok
11	300	24.32	Ok
12	330	0.93	Not ok
13	360	0.61	Not ok
14	390	1.81	Ok
15	420	1.58	Ok
16	450	1.70	Ok
17	480	0.79	Not ok
18	510	0.70	Not ok
19	540	1.59	Ok
20	570		Not ok
21	600	4.22	Ok
22	630	4.33	Ok
23	660	4.04	Ok
24	690		Not ok
25	720	4.78	Ok
26	750	7.46	Ok
27	780	5.35	Not ok
28	810	2.62	Not ok
29	840	6.22	Not ok
30	870	7.69	Not ok
31	900		Not ok
32	930	7.65	Not ok
33	960		Not ok
34	990	2.82	Not ok
35	1020	9.14	Ok
36	1050	7.97	Not ok
37	1080	4.57	Not ok
38	1110	7.69	Not ok
39	1140	11.83	Ok
40	1170		Not ok
41	1200		Not ok
42	1230	18.85	Ok
43	1260	12.20	Ok
44	1290	2.80	Not ok
45	1320	2.02	Not ok
46	1350	26.49	Ok
47	1380	32.85	Ok

S.No.	Chainage (m)	Discharge, (Q), (m ³ /s)	“Ok” (if Q is as per P [*]), else “Not ok”
48	1410	14.44	Ok
49	1440	8.84	Ok
50	1470	23.40	Ok
51	1500	24.19	Ok
52	1530	7.31	Not ok
53	1560	12.49	Ok
54	1590	7.58	Not ok
55	1620		Not ok
56	1650		Not ok
57	1680		Not ok
58	1710	11.68	Ok
59	1740	6.73	Not ok
60	1770		Not ok
61	1800		Not ok
62	1830	1.98	Not ok
63	1860		Not ok
64	1890	9.71	Ok
65	1920	4.83	Not ok
66	1950	5.18	Not ok
67	1980	4.63	Not ok
68	2010	1.06	Not ok
69	2040	4.87	Not ok
70	2070	10.76	Ok
71	2100	4.05	Not ok
72	2130	3.66	Not ok
73	2160	4.92	Not ok
74	2190	3.70	Not ok
75	2220	5.27	Not ok
76	2250	2.28	Not ok
77	2280	1.39	Not ok
78	2310	2.33	Not ok
79	2340	4.80	Not ok
80	2370	6.90	Not ok
81	2400	8.82	Ok
82	2430	9.92	Ok
83	2460	12.11	Not ok
84	2490	16.78	Not ok
85	2520	20.15	Ok
86	2550	21.06	Ok
87	2580		Not ok
88	2610	6.94	Not ok
89	2640	5.90	Not ok
90	2670	7.18	Not ok
91	2700	3.43	Not ok
92	2730	4.50	Not ok
93	2760	4.76	Not ok
94	2790	7.17	Not ok
95	2820	7.72	Not ok
96	2850	3.80	Not ok
97	2880		Not ok
98	2910	4.83	Not ok
99	2940	12.28	Not ok

S.No.	Chainage (m)	Discharge, (Q), (m ³ /s)	“Ok” (if Q is as per P [*]), else “Not ok”
100	2970	10.62	Not ok
101	3000	2.70	Not ok
102	3030	3.81	Not ok
103	3060	7.43	Not ok
104	3090	13.84	Not ok
105	3120	30.55	Ok
106	3150	13.20	Not ok
107	3180	10.69	Not ok
108	3210	18.78	Ok
109	3240	5.50	Not ok
110	3270	8.18	Not ok
111	3300	5.75	Not ok
112	3330	13.13	Not ok
113	3360		Not ok
114	3390	7.18	Not ok
115	3420	7.98	Not ok
116	3450	19.03	Ok
117	3480	12.19	Not ok
118	3510	3.08	Not ok
119	3540	3.10	Not ok
120	3570		Not ok
121	3600	26.43	Ok
122	3630	20.49	Ok
123	3660	22.38	Ok
124	3690	14.00	Not ok
125	3720	13.10	Not ok
126	3750	4.51	Not ok
127	3780	25.24	Ok
128	3810		Not ok
129	3840	14.24	Not ok
130	3870		Not ok
131	3900	11.61	Not ok
132	3930	32.95	Ok
133	3960	28.85	Ok
134	3990	17.67	Ok
135	4020	46.35	Ok
136	4050	55.35	Ok
137	4080		Not ok
138	4110	17.53	Ok
139	4140	88.27	Ok
140	4170		Not ok
141	4200		Not ok
142	4230		Not ok
143	4260	181.23	Ok
144	4290		Not ok
145	4320	55.92	Ok
146	4350	20.52	Not ok
147	4380		Not ok
148	4410		Not ok
149	4440	10.53	Not ok
150	4470	9.64	Not ok
151	4500	19.02	Not ok

S.No.	Chainage (m)	Discharge, (Q), (m ³ /s)	“Ok” (if Q is as per P [*]), else “Not ok”
152	4530	17.16	Not ok
153	4560	36.68	Ok
154	4590	10.21	Not ok
155	4620	37.34	Ok
156	4650	29.14	Ok
157	4680	25.17	Ok
158	4710	30.09	Ok
159	4740	15.65	Not ok
160	4770		Not ok
161	4800	11.10	Not ok
162	4830	32.11	Ok
163	4860		Not ok
164	4890	20.28	Not ok
165	4920	14.27	Not ok
166	4950	26.98	Ok
167	4980	27.48	Ok
168	5010	6.59	Not ok
169	5040		Not ok
170	5070		Not ok
171	5100	29.47	Ok
172	5130	3.28	Not ok
173	5160		Not ok
174	5190	87.60	Ok
175	5220	8.33	Not ok
176	5250	5.74	Not ok
177	5280	13.96	Not ok
178	5310	4.08	Not ok
179	5340		Not ok
180	5370	17.76	Not ok
181	5400	19.42	Not ok
182	5430	17.77	Not ok
183	5460	17.53	Not ok
184	5490		Not ok
185	5520		Not ok
186	5550	4.33	Not ok
187	5580		Not ok
188	5610	21.90	Not ok
189	5640		Not ok
190	5670	54.50	Ok
191	5700		Not ok
192	5730	72.49	Ok
193	5760	26.33	Ok
194	5790		Not ok
195	5820	106.64	Ok
196	5850	52.65	Ok
197	5880	16.15	Not ok
198	5910		Not ok
199	5940	7.00	Not ok
200	5970	23.54	Not ok
201	6000		Not ok
202	6030	55.87	Ok
203	6060	60.24	Ok

S.No.	Chainage (m)	Discharge, (Q), (m ³ /s)	“Ok” (if Q is as per P [*]), else “Not ok”
204	6090	75.79	Ok
205	6120	4.74	Not ok
206	6150		Not ok
207	6180	4.59	Not ok
208	6210	7.11	Not ok
209	6240	17.26	Not ok
210	6270	44.12	Ok
211	6300	49.36	Ok
212	6330		Not ok
213	6360		Not ok
214	6390	16.30	Not ok
215	6420	13.90	Not ok
216	6450	18.38	Not ok
217	6480	15.95	Not ok
218	6510		Not ok
219	6540	59.02	Ok
220	6570	23.50	Not ok
221	6600		Not ok
222	6630	11.06	Not ok
223	6660	31.58	Not ok
224	6690	79.61	Ok
225	6720	112.67	Ok
226	6750	37.14	Not ok
227	6780	2.80	Not ok
228	6810	1.87	Not ok
229	6840		Not ok
230	6870		Not ok
231	6900	9.51	Not ok
232	6930		Not ok
233	6960	29.64	Not ok
234	6990	148.87	Ok
235	7020	36.35	Not ok
236	7050	11.52	Not ok
237	7080	12.00	Not ok
238	7110	156.26	Ok
239	7140	76.15	Ok
240	7170		Not ok
241	7200	38.69	Not ok
242	7230	1.07	Not ok
243	7260	5.95	Not ok
244	7290	3.68	Not ok
245	7320		Not ok
246	7350	29.86	Not ok
247	7380		Not ok
248	7410	247.19	Ok
249	7440	68.68	Ok
250	7470	30.32	Not ok
251	7500	12.70	Not ok
252	7530	7.23	Not ok
253	7560	6.91	Not ok
254	7590	4.85	Not ok
255	7620		Not ok

S.No.	Chainage (m)	Discharge, (Q), (m ³ /s)	“Ok” (if Q is as per P [*]), else “Not ok”
256	7650		Not ok
257	7680	74.37	Ok
258	7710	46.82	Ok
259	7740	7.99	Not ok
260	7770	8.55	Not ok
261	7800	7.47	Not ok
262	7830	6.20	Not ok
263	7860	4.92	Not ok
264	7890	9.73	Not ok
265	7920	7.66	Not ok
266	7950	9.63	Not ok
267	7980	17.23	Not ok
268	8010	4.76	Not ok
269	8040	99.41	Ok
270	8070		Not ok
271	8100	2.07	Not ok
272	8130	6.00	Not ok
273	8160		Not ok
274	8190		Not ok
275	8220		Not ok
276	8250	5.51	Not ok
277	8280	5.59	Not ok
278	8310	195.08	Ok
279	8340	70.68	Ok
280	8370	83.33	Ok
281	8400	22.51	Not ok
282	8430	2.28	Not ok
283	8460	9.62	Not ok
284	8490	13.44	Not ok
285	8520	7.44	Not ok
286	8550	19.04	Not ok
287	8580	49.04	Not ok
288	8610	16.51	Not ok
289	8640	1.34	Not ok
290	8670	0.41	Not ok
291	8700	1.75	Not ok
292	8730	3.76	Not ok
293	8760	9.21	Not ok
294	8790		Not ok
295	8820	0.00	Not ok
296	8850	1.28	Not ok
297	8880	1.12	Not ok
298	8910	44.25	Not ok
299	8940	57.06	Ok
300	8970	9.43	Not ok
301	9000	4.37	Not ok
302	9030	12.36	Not ok
303	9060	3.43	Not ok
304	9090	13.17	Not ok
305	9120	31.40	Not ok
306	9150	41.76	Not ok
307	9180	20.57	Not ok

S.No.	Chainage (m)	Discharge, (Q), (m ³ /s)	“Ok” (if Q is as per P [*]), else “Not ok”
308	9210	9.48	Not ok
309	9240	12.86	Not ok
310	9270	6.27	Not ok
311	9300	0.36	Not ok
312	9330	18.25	Not ok
313	9360	29.85	Not ok
314	9390	0.26	Not ok
315	9420		Not ok
316	9450	2.45	Not ok
317	9480	8.29	Not ok
318	9510		Not ok
319	9540	0.28	Not ok
320	9570		Not ok
321	9600	189.38	Ok
322	9630	9.01	Not ok
323	9660	0.49	Not ok
324	9690	0.29	Not ok
325	9720	1.01	Not ok
326	9750		Not ok
327	9780	0.95	Not ok
328	9810		Not ok
329	9840	0.28	Not ok
330	9870	0.45	Not ok
331	9900	0.00	Not ok
332	9930	1.22	Not ok
333	9960		Not ok
334	9990	1.00	Not ok
335	10020	1.09	Not ok
336	10050	1.12	Not ok
337	10080	0.55	Not ok
338	10110		Not ok
339	10140		Not ok
340	10170		Not ok
341	10200		Not ok
342	10230		Not ok
343	10260	1.64	Not ok
344	10290	0.94	Not ok
345	10320		Not ok
346	10350	0.17	Not ok
347	10380	0.24	Not ok
348	10410		Not ok
349	10440	3.60	Not ok
350	10470	2.13	Not ok
351	10500		Not ok
352	10530	2.16	Not ok
353	10560	0.11	Not ok
354	10590	0.04	Not ok
355	10620	0.00	Not ok
356	10650	0.00	Not ok
357	10680	6.97	Not ok
358	10710	0.00	Not ok
359	10740	0.00	Not ok

S.No.	Chainage (m)	Discharge, (Q), (m ³ /s)	“Ok” (if Q is as per P [*]), else “Not ok”
360	10770	0.00	Not ok
361	10800		Not ok
362	10830	0.35	Not ok
363	10860	8.47	Not ok
364	10890		Not ok
365	10920		Not ok
366	10950	6.37	Not ok
367	10980	4.01	Not ok
368	11010	1.42	Not ok
369	11040	0.89	Not ok
370	11070	0.42	Not ok
371	11100	0.27	Not ok
372	11130	0.35	Not ok
373	11160	0.15	Not ok
374	11190	0.32	Not ok
375	11220	0.39	Not ok
376	11250	0.51	Not ok
377	11280	0.48	Not ok
378	11310	0.15	Not ok
379	11340		Not ok
380	11370	5.07	Not ok
381	11400	1.26	Not ok
382	11430	1.27	Not ok
383	11460	1.54	Not ok
384	11490	1.03	Not ok
385	11520		Not ok
386	11550	0.09	Not ok
387	11580	0.06	Not ok
388	11610	0.08	Not ok
389	11640	0.29	Not ok
390	11670	1.53	Not ok
391	11700	1.89	Not ok
392	11730	0.72	Not ok
393	11760	0.74	Not ok
394	11790	0.48	Not ok
395	11820	0.55	Not ok
396	11850		Not ok
397	11880	0.40	Not ok
398	11910	0.49	Not ok
399	11940		Not ok
400	11970		Not ok
401	12000	0.38	Not ok
402	12030	1.21	Not ok
403	12060	0.51	Not ok
404	12090	1.37	Not ok
405	12120	5.04	Not ok
406	12150	3.91	Not ok
407	12180	0.86	Not ok
408	12210	0.56	Not ok
409	12240	0.46	Not ok
410	12270	1.38	Not ok
411	12300	0.75	Not ok

S.No.	Chainage (m)	Discharge, (Q), (m ³ /s)	“Ok” (if Q is as per P [*]), else “Not ok”
412	12330	0.70	Not ok
413	12360	1.12	Not ok
414	12390	0.00	Not ok
415	12420	2.65	Not ok
416	12450	0.00	Not ok
417	12480		Not ok
418	12510	1.47	Not ok
419	12540		Not ok
420	12570	0.60	Not ok
421	12600	0.72	Not ok
422	12630	0.70	Not ok
423	12660	1.47	Not ok
424	12690		Not ok
425	12720		Not ok
426	12750		Not ok
427	12780	2.53	Not ok
428	12810	0.13	Not ok
429	12840	0.07	Not ok
430	12870	0.81	Not ok
431	12900	1.74	Not ok
432	12930	4.36	Not ok
433	12960		Not ok
434	12990	0.24	Not ok

- ❖ The computed values show that in most of the examined sections of the existing N Choe channel, the maximum discharge capacity is less than the incoming flow. This clearly indicates that the existing channel cannot accommodate the full volume of water during peak events as it is undersized. As a consequence, overflow occurs and flooding is inevitable.

Analysis of existing L-Profile of N-Choe channel vis-à-vis level of stormwater drains

The AutoCAD drawing of the existing Longitudinal profile (L-profile) of the N-Choe channel has been made using topographical survey data. In addition, Reduced Levels (RLs) of the stormwater drains in the city of Chandigarh which are discharging into N-Choe, have been compiled. By overlaying these two datasets—namely, the existing L-profile of the channel bed and the soffit (invert) elevations of the stormwater drains—analysis was done. The drawing made by combining the above two datasets is shown below in Figure 5a, 5b, 5c and 5d.

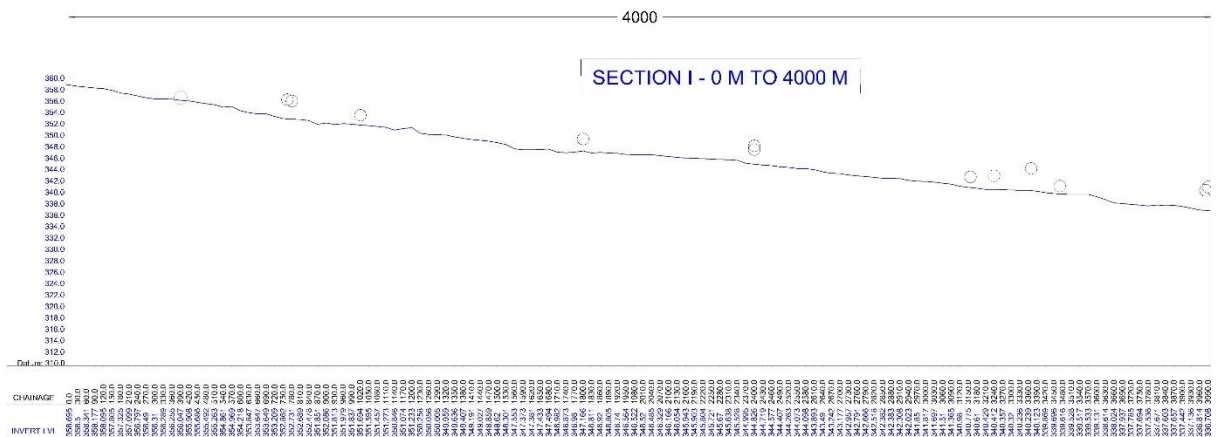


Figure 5a – Existing L-profile of N-Choe from chainage 0m to 4000m vis-à-vis stormwater drain level



Figure 5b – Existing L-profile of N-Choe from chainage 4000m to 7910m vis-à-vis stormwater drain level

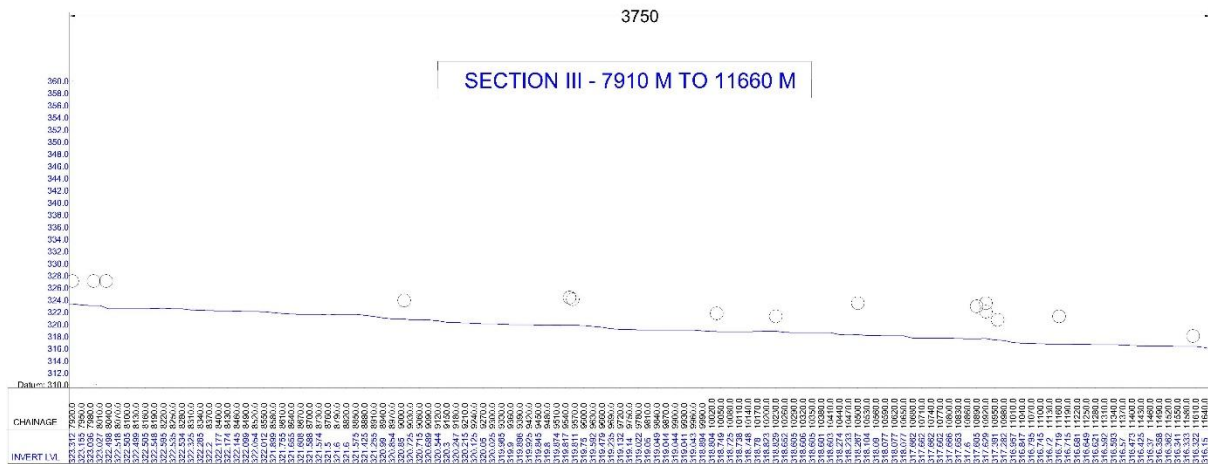


Figure 5c – Existing L-profile of N-Choe from chainage 7910m to 11660m vis-à-vis
stormwater drain level

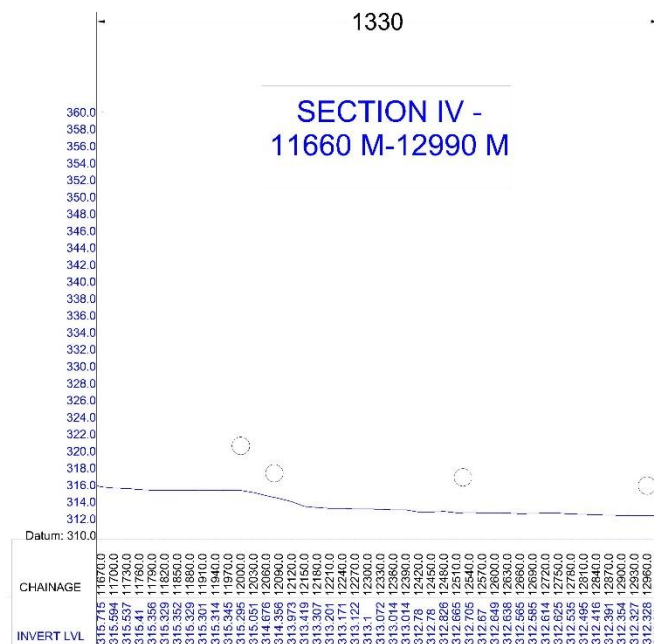


Figure 5d – Existing L-profile of N-Choe from chainage 11660m to 12990m vis-à-vis
stormwater drain level

The comparative evaluation reveals several critical cross-sections where the R.L. of bed of existing N-Choe exceeds the soffit level of the adjacent stormwater drains. This inversion results in hydraulic backwater conditions: during peak discharge events, instead of flowing out freely, the stormwater discharges encounter a reverse hydraulic gradient—causing flow

retardation or reversal into the drainage network. Such bottlenecks lead to localized inundation and flooding in the adjoining urban areas.

5. INTERPRETATION OF RESULTS

The data analysis results indicate that the existing N-Choe channel's discharge carrying capacity at most of the sections is insufficient to handle the total inflow (though it is sufficient but only at very few sections), leading to potential overflow and erosion risks. This inadequacy necessitates a comprehensive redesign of the channel to enhance its conveyance efficiency and ensure flood mitigation. Proposed modifications along with the remedial measures are discussed below in detail. These interventions aim to align the channel's design with current hydrological demands, thereby reducing flood risks and promoting sustainable water management.

Proposed Modifications:

❖ *Design of prismatic channel to carry the design discharge:*

As per the design parameters of discharge, slope and cross section of N-Choe, it is seen that velocity of flow during peak season is high with regard to the natural bed strata of the Choe. Thus, the bed width of the channel has been increased and the longitudinal slope is reduced so as to reduce the velocity of flow. The design of the channel has been done in accordance with Indian Standards (IS 10430:2000) using Manning's equation. A trapezoidal section with rounded corners has been adopted as shown in Figure 6.

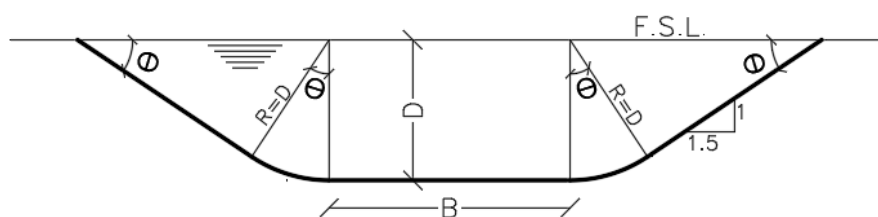


Figure 6- Adopted Trapezoidal Section of the N-Choe

Proposed L- profile of the channel to carry the design discharge

The proposed L-profile of the channel is designed keeping in view the constraint in opting for concrete lining in the N-Choe. The channel has been divided in four sections having varying longitudinal slopes, keeping in view the existing bed slope and the location of storm drains and

the depth of flow required. Falls of 0.5 m height are proposed at various locations to cater for the hydraulic requirements of discharge, depth and velocity of flow. For design purpose the Choe has been divided in four sections and the design discharge for these sections is adopted as per Table 3.

Table 3 - Design discharge at various sections of N-Choe

Section No. of N-Choe	Chainage (m)	Design Discharge (m ³ /s)
I	0-4000	20
II	4000-7910	40
III	7910-11660	55
IV	11660-12990	60

The design calculations for different sections along N-Choe with proposed modifications are shown in Table 4.

Table 4 - Design calculations for different sections with proposed modifications

Design calculations for Section I:						
Chainage	=	0	m	to	4000	m
L-Slope	=	1	in	2000		
Side Slope	=	1.5	:	1		
tan Θ	=	0.67				
Θ	=	0.59	radians	=	33.71	deg
Rugosity coefficient n	=	0.0225				
Bed Width B	=	6	m			
Depth of Flow D	=	1.8	m			
Area of Cross Section A	=	17.565	m ²			
Perimeter of the X- Section P	=	13.52	m			
Hydraulic Mean Depth R	=	1.300	m			
Velocity of Flow V	=	1.18	m/s	OK		
Discharge capacity Q	=	20.73	m ³ /s			
Design Discharge	=	20	m ³ /s	OK		
Design calculations for Section II:						

Chainage	=	4000	m	to	7910	m
L-Slope	=	1	in	3000		
Side Slope	=	1.5	:	1		
tan Θ	=	0.67				
Θ	=	0.59	radians	=	33.71	deg
Rugosity coefficient n	=	0.0225				
Bed Width B	=	8	m		15.56	
Depth of Flow D	=	2.52	m			
Area of Cross Section A	=	33.420	m ²			
Perimeter of the X- Section P	=	18.524	m			
Hydraulic Mean Depth R	=	1.804	m			
Velocity of Flow V	=	1.2	m/s	OK		
Discharge capacity Q	=	40.1	m ³ /s			
Design Discharge	=	40	m ³ /s	OK		
Design calculations for Section III:						
Chainage	=	7910	m	to	11660	m
L-Slope	=	1	in	2500		
Side Slope	=	1.5	:	1		
tan Θ	=	0.67				
Θ	=	0.59	radians	=	33.71	deg
Rugosity coefficient n	=	0.02				
Bed Width B	=	8	m		16.1	
Depth of Flow D	=	2.7	m			
Area of Cross Section A	=	36.822	m ²			
Perimeter of the X- Section P	=	19.275	m			
Hydraulic Mean Depth R	=	1.910	m			
Velocity of Flow V	=	1.54	m/s	OK		
Discharge capacity Q	=	56.71	m ³ /s			
Design Discharge	=	55	m ³ /s	OK		
Design calculations for Section IV:						
Chainage	=	11660	m	to	12990	m

L-Slope	=	1	in	2000		
Side Slope	=	1.5	:	1		
$\tan \Theta$	=	0.67				
Θ	=	0.59	radians	=	33.71	deg
Rugosity coefficient n	=	0.02				
Bed Width B	=	8	m			
Depth of Flow D	=	2.7	m			
Area of Cross Section A	=	36.82	m ²			
Perimeter of the X- Section P	=	19.28	m			
Hydraulic Mean Depth R	=	1.91	m			
Velocity of Flow V	=	1.72	m/s	OK		
Discharge capacity Q	=	63.33	m ³ /s			
Design Discharge	=	60	m ³ /s	OK		

The summary of the Cross-sections (X- sections) is given in Table 5.

Table 5 - Summary of X- sections of N-Choe

Section	Chainage (m)	L-Slope, (S)	Bed width, (B), (m)	Depth of Flow, (D), (m)	Velocity, (V), (m/s)	Discharge, (Q), (m ³ /s)
I	0-4000	1 in 2000	6	1.8	1.18	20.73
II	4000-7910	1 in 3000	8	2.52	1.2	40.1
III	7910-11660	1 in 2500	8	2.7	1.54	56.71
IV	11660-12990	1 in 2000	8	2.7	1.72	63.33

Remedial Measures:

- **Channel Lining:** Apply stone pitching lining (as shown below in Figure 7) selectively—specifically at locations where energy dissipation structures called falls have been recommended and along the stretch between chainages 7,910 m and 12,990 m due to high velocity of flow along this stretch. This partial lining approach helps reinforce vulnerable sections without altering the channel's natural characteristics needlessly.

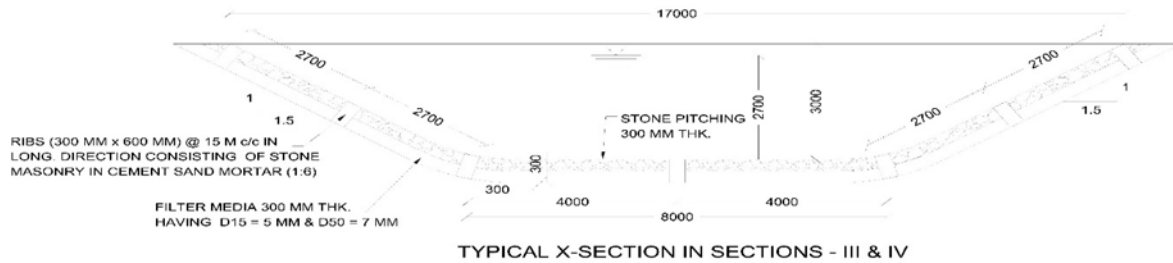
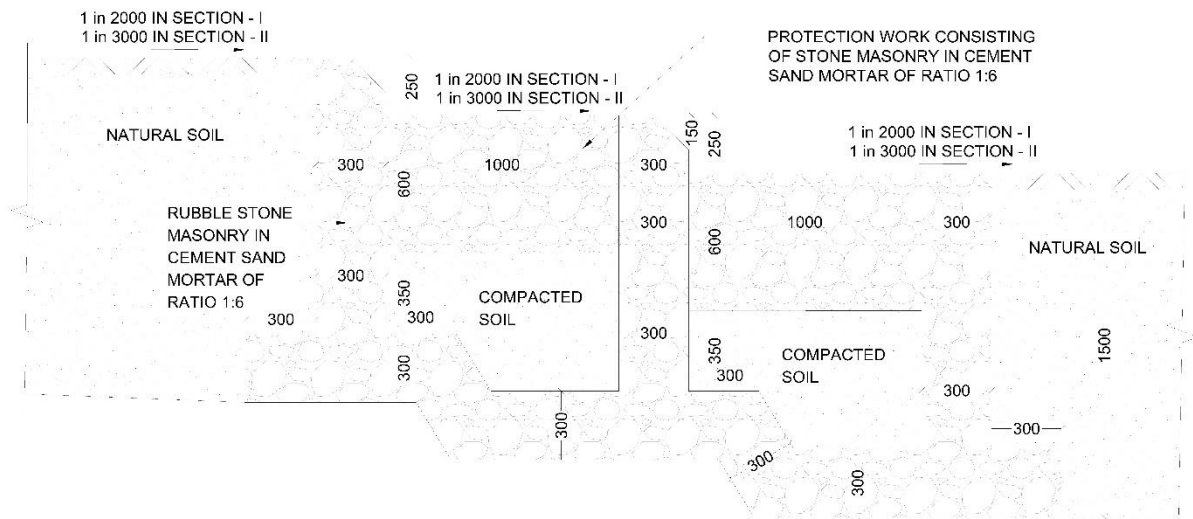


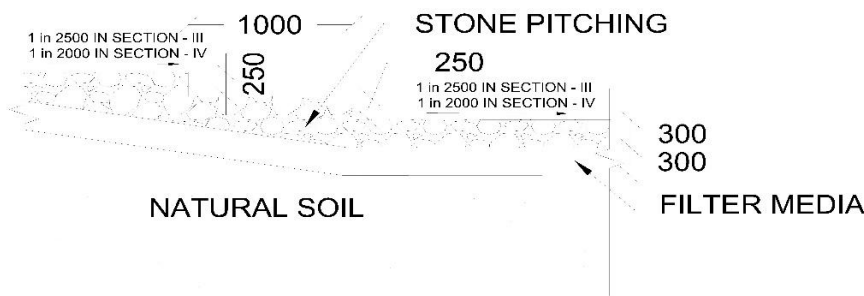
Figure 7 – Stone Pitching in typical X-section of sections III and IV

- Velocity Control Measures:** Introduce structures such as falls (as shown below in Figure 8a and 8b) to control flow velocity and prevent structural damage. Falls of 0.5 m height are strategically introduced at regular intervals along the channel alignment. These falls act as grade-control structures, dissipating energy and reducing flow velocity incrementally, thus protecting the channel against erosion and downstream flooding. To reinforce these structures, stone-pitching lining of 300 mm thickness has been recommended. This thickness aligns with standard practice, as pitching layers typically vary from 0.3 to 1.0 m depending on discharge and velocity conditions. The stone-pitching not only offers a robust protective armour against scour but also maintains ecological compatibility with the channel's natural state, ensuring both structural stability and environmental sensitivity.



TYPICAL DETAIL OF FALL OF 500 MM IN TWO STEPS
IN SECTIONS - I & II

Figure 8a – Typical detail of fall in sections I and II



TYPICAL DETAIL OF FALL OF 500 MM IN TWO STEPS
FOR SECTIONS - III & IV

Figure 8b – Typical detail of fall for sections III and IV

- **Optimal Slope Selection:** Determine the most economical and effective slope by considering factors like topography, soil type, flow rate, and erosion potential. The slope of the proposed section (as discussed above in Table 5) is decided keeping in mind the existing slope of the channel of N-Choe so that minimum amount of cutting and filling is required and thus, the proposed section is economical.
- **Regrading of Channel Bed:** Lower the bed of the channel at critical points to ensure a consistent slope that facilitates proper flow direction towards the stormwater drains and hence preventing the backflow of water. The proposed L-profile of the N-Choe channel (as shown below in Figure 9a, 9b, 9c and 9d) has been decided keeping in mind the consequences due to its existing L-profile vis-à-vis level of stormwater drains exiting in it.

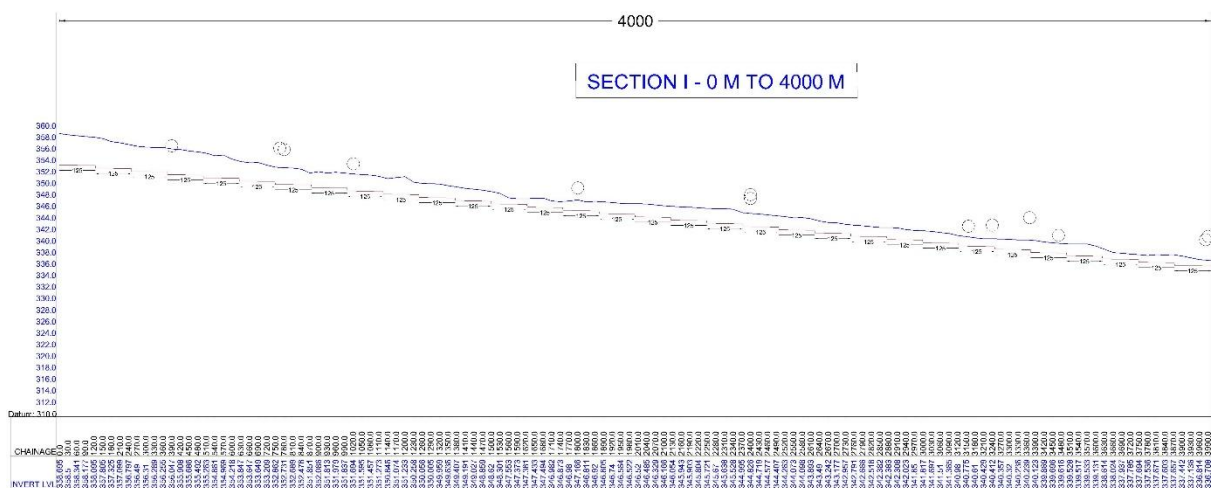


Figure 9a – Proposed L-profile of N-Choe from chainage 0m to 4000m

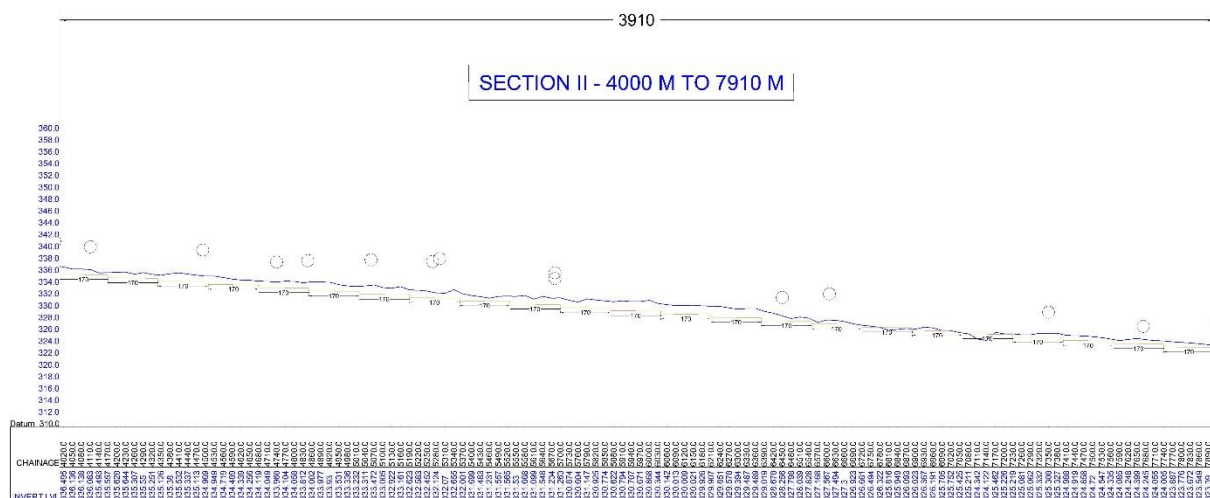


Figure 9b – Proposed L-profile of N-Choe from chainage 4000m to 7910m

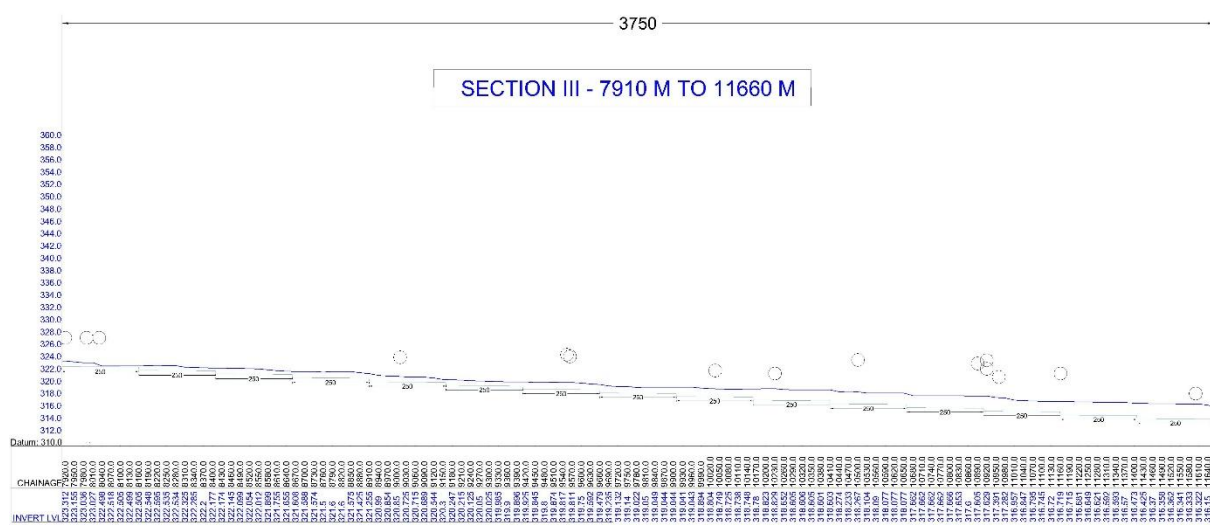


Figure 9c – Proposed L-profile of N-Choe from chainage 7910m to 11660m

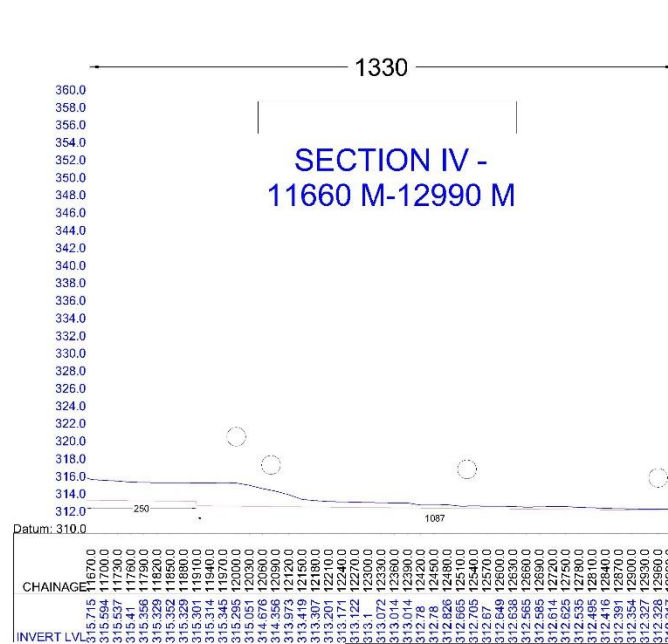


Figure 9d – Proposed L-profile of N-Choe from chainage 11660m to 12990m

By implementing these proposed modifications and remedial measures, the drainage structure along N-Choe can be significantly improved, addressing the identified issues and enhancing the overall efficiency and sustainability of the system.

6. CONCLUSION

The study titled "**Study and design of drainage structure and its characteristics along N-Choe in Chandigarh region**" aimed to assess the existing drainage infrastructure and propose necessary improvements to enhance its efficiency and capacity. The detailed analysis of the existing N-Choe channel with the help of topographical survey and soil investigation has revealed critical issues affecting the channel's performance, necessitating a comprehensive redesign. It has been found that the discharge capacity of the existing N-Choe channel needs to be augmented by changing its L-profile and cross-sectional profiles at various locations accordingly. The discharge capacity has been increased by increasing the bed width to retain the natural strata of the N-Choe.

From chainage 0 m to 7910 m, the N-Choe has been kept in its natural form, except in the fall portions stone pitching is recommended. From chainage 7910 m to 12990 m, the stone pitching in the bed and the slopes is recommended due to the increase in the velocity of flow.

Key Findings and Recommendations of the Study:

- **Inadequate Discharge Capacity:** The existing N-Choe channel lacks sufficient capacity to handle the total discharge, leading to potential flooding and erosion risks. Therefore, the discharge carrying capacity of N-Choe has been increased by increasing the bed width to retain the natural strata of the N-Choe. The calculations and proposed modifications of it are discussed above in detail.
- **Unlined Channel Issues and Velocity Concerns:** The N-Choe channel is currently unlined, resulting in a relatively low permissible flow velocity due to the roughness and erodibility of its natural cross-section. According to standard references, maximum safe velocities in unlined earth channels vary by soil type—typically between 0.7 to 1.4 m/s for loamy or gravel soils, and up to 2.0 m/s only in stony or rocky sections to avoid erosion. An analysis of longitudinal flow from chainage 0 m to 12,990 m reveals that flow velocities progressively increase. Beyond chainage ~7,910 m, the velocity surpasses the safe threshold for unlined channels—indicating a high risk of scour and erosion of both the channel bed and banks. To preserve the channel's natural, unlined character while mitigating erosion, two interventions are proposed. (i) From chainage 0 m to 7910 m, the N-Choe has been kept in its natural form, except in the fall portions stone pitching is recommended. (ii) From chainage 7910 m to 12990 m, the stone pitching in the bed and slopes is recommended due to increase in the velocity of flow.
- **Steep Bed Slope & Flooding Hazard:** The existing bed slope of the N-Choe channel is excessively steep, leading to flow velocities that far exceed the permissible limits for natural, unlined earth channels. Such high gradients have resulted in elevated velocities that have repeatedly caused bank scour and flood events during peak discharges. To resolve this, the channel has been divided into four longitudinal sections, each proposed with a bed slope aligned with the natural terrain gradient, thereby minimizing earthwork (cutting/filling) and ensuring the solution is both economical and sustainable. Additionally, falls (grade-control structures) of 0.5 m height are recommended at regular intervals to dissipate hydraulic energy and further regulate flow velocity. This design approach ensures that velocities within each section remain within permissible limits, effectively preventing erosion, enhancing conveyance efficiency, and significantly reducing flood risk without extensive

structural intervention. The calculations and proposed modifications of it are discussed above in detail.

- **Longitudinal Profile Issues:** The existing L-profile of N-Choe is such that its bed level is above the soffit level of stormwater drains exiting in it at certain locations, causing water to backflow and overflow, leading to flooding in adjacent areas. As a result, a new profile has been proposed for the N-Choe channel such that its bed level is lower than the soffit level of the stormwater drains at all locations so as to prevent the backflow of water and thus mitigating the problem of flooding.

LIST OF ABBREVIATIONS

N-Choe: Northern Choe

DGPS: Differential Global Positioning System

TS: Total Station

DCPT: Dynamic Cone Penetrometer Test

SPT: Standard Penetration Test

NBS: Nature based solutions

SCP: Sponge City Program

L-Profile: Longitudinal Profile

R.L.: Reduced Level

IS: Indian Standards

X-section: Cross-section

7. DECLARATIONS

Conflicts of interest: The authors declare no conflict of interest/competing interests.

Declaration of generative AI and AI-assisted technologies in the writing process: During the preparation of this work, the author(s) used ChatGPT, a generative AI tool in order to improve the readability and language of manuscripts by offering suggestions for clearer, more concise writing. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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