

INSTITUT PENYELIDIKAN HIDRAULIK KEBANGSAAN MALAYSIA
NATIONAL HYDRAULIC RESEARCH INSTITUTE OF MALAYSIA
(NAHRIM)

KEMENTERIAN SUMBER ASLI DAN ALAM SEKITAR
MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
(NRE)



LAPORAN AKHIR

FINAL REPORT

THE DEVELOPMENT OF NUMERICAL MODELLING FOR SUNGAI CHINI, PAHANG (ASSESSMENT ON THE STRUCTURE OF WEIR)

Report No.: NAHRIM.PKLS.10/2014
(Section: Hydrodynamic Modelling)

MARCH 2015/ *MARCH 2015*



PROJECT TEAM MEMBERS

National Hydraulic Research Institute of Malaysia (NAHRIM)

- 1. Project Director**
Datuk Ir. Hj. Ahmad Jamalluddin bin Shaaban
- 2. Project Manager**
Prof. Dr. Nasehir Khan E.M Yahaya
- 3. Coordinator**
Azman Mat Jusoh & Suriyani binti Awang

NUMERICAL MODELLING TEAM

- 1. Numerical Modeller (Hydrodynamic)**
Liew Yuk San
- 2. Numerical Modeller (Hydrodynamic)**
Muhammad Saufi Ishak

DATA COLLECTION TEAM

- 1. Senior Research Officer**
Wan Ahmad Hafiz bin Wan Mohamed Azhary
- 2. Senior Technical Assistant**
Ahmad Tarmizi bin Alwi
- 3. Technical Assistant**
Mohd Amram Mohd Nor
- 4. Technician**
Mohd Hafiz Zulkifli
- 5. Technician**
Mohammad Faizan Bin Sahnin
- 6. Technician**
Shahdy Izuan Samsuddin

TABLE OF CONTENT

Topic	Title	Page
	Table of Content	i
	Preface	ii
	Acknowledgements	iii
	Executive Summary	iv
	List of Figures	v
	List of Tables	xv
1.0	INTRODUCTION	1
1.1	Background	1
1.2	Research Objectives	2
1.3	Research Scopes	2
1.4	Research Site	2
2.0	RESEARCH METHODOLOGY	4
3.0	DATA ACQUISITION AND DATA COLLECTION	5
3.1	Topographic Map	5
3.2	Hydrological Stations	5
3.3	River System	8
3.4	Land Use Map	9
4.0	DATA PROCESSING	10
4.1	Hydrological Analysis	10
5.0	MODEL SET-UP	12
5.1	Hydrodynamic Software	12
5.2	River Hydraulic Model	12
5.3	Model Calibration and Verification	13
6.0	MODEL SIMULATION	22
6.1	Scenario 1: Current (Landuse) and Baseline (Meteorology)	22
6.2	Scenario 2: Current (Landuse) and Future (Meteorology)	24
6.3	Scenario 3: Future (Landuse) and Baseline (Meteorology)	27
6.4	Scenario 4: Future (Landuse) and Future (Meteorology)	30
7.0	RESULTS AND DISCUSSION	33
7.1	Impact of Landuse Change	33
7.2	Impact of Climate Change	45
7.3	Impact of Landuse and Climate Change	57
7.4	Assessment on the weir modification	72
8.0	CONCLUSION AND RECOMMENDATION	85
8.1	Conclusion	85
8.2	Recommendation	86
9.0	REFERENCES	92

PREFACE

Tasik Chini is located near the Pahang River in the Pahang state is the second largest natural freshwater lake in Malaysia. A study from Malaysian Nature Society found that there were 309 species of plants including aquatic plants, 92 species of birds and 144 species of aquatic life in the area of Tasik Chini. However, Tasik Chini's condition became worse when a small dam or weir was built in 1995 to retain the lake's water for tourism purposes. These caused the water level of the lake has risen and water movement to become less dynamic. Fish activities were also affected and water current became unstable, although the lake water was defined as safe for recreational purposes. The content of contaminants were also increased, including certain metals in lake water is not compatible with the original life of the lake led to the extinction of certain species of fish, including the lotus plant-*Nelumbo nucifera*, which became the main attractions and the identity of the lake. Thus, there is an urgent need for a concerted research in Tasik Chini.

The output of this study will be the assessment on the impact of the existing weir under baseline and future scenario for various return periods (10-, 20-, 25-, 50- and 100-year Average Recurrence Interval (ARI)) to the hydrodynamic of Sg. Chini. This is done through the simulation using hydrodynamic modelling based on the calibrated and verified hydrological model. From the simulations, recommendation of appropriate measures for flood and river management has been proposed to minimise the impact of flooding and at the same time to sustain the growth of lotus population at Tasik Chini without disrupting the navigational system along Sungai Chini.

Ir. Hj. Ahmad Jamalluddin bin Shaaban

Director-General

National Hydraulic Research Institute of Malaysia (NAHRIM)

Ministry of Natural Resources and Environment (NRE)

ACKNOWLEDGEMENTS

NAHRIM are glad that this project on the development of numerical modelling on the assessment of weir for Sungai Chini, Pahang was successfully completed. The overall completion of this project is made possible from the cooperation and commitment by various parties.

A special appreciation is extended to the Ministry of Natural Resources and Environment Malaysia (NRE) on their kindness to fund this project. NAHRIM also would like to express our gratitude to the Department of Irrigation and Drainage (DID) Malaysia for the huge amounts of data provided such as hydrological information and river survey data.

Apart from that, a deep appreciation is also due to Water Resources and Climate Change Research Center for their hydrological modelling data; and Coastal Management and Oceanography Research Center for their services in equipment installation were also highly appreciated. Lastly, NAHRIM are thankful to those who have involved and commented for the improvement of the overall projects output.

Director

River Basin Research Centre

National Hydraulic Research Institute of Malaysia (NAHRIM)

Ministry of Natural Resources and Environment (NRE)

EXECUTIVE SUMMARY

Tasik Chini is the second largest natural freshwater lake in Malaysia located in the southeast region of Pahang, Malaysia. The catchments area about 49.8 km² consists of 12 small lakes and receiving water flow from several river tributaries. Flow from Tasik Chini will then discharge into Sungai Chini before connecting with Sg. Pahang. The total length of Sg. Chini is at 4.8 km and intersects at km 84 of Sg. Pahang flowing towards South China Sea.

There were 309 species of plants including aquatic plants, 92 species of birds and 144 species of aquatic life in the area of Tasik Chini. Due to the development of Tasik Chini, the environment has greatly changed the topography and the pattern of land use in the area which contributes to the hydrological imbalance and altering the entire ecosystem of the lake. Thus, there is an urgent need for a concerted research in Tasik Chini. This study aimed to develop a hydrodynamic model for Sungai Chini, Pahang and its feeder rivers to assess the impact of the existing weir under baseline and future scenario for various return periods (10-, 20-, 25-, 50- and 100-year Average Recurrence Interval (ARI)) to the hydrodynamic of Sg. Chini.

The methodology of the study comprises of data acquisition and data collection of hydrological data (HEC-HMS times series) and hydraulic data such as water level and discharge data for Sungai Chini and its feeder rivers; setting up of hydrodynamic modelling; model calibration and verification and follow by model simulations and assessment. Two assessments were done on the existing weir under land use and climate change scenarios and assessments on weir modification.

Results for assessment on the impact of the combination of landuse change and climate change for various ARIs show a significant increment in both water level and flow for various ARIs under the impact of both landuse change and climate change with increase of 0.932 m (8.451%) to 1.981 m (14.010%) for water level and increase of 2.434 m³/s (12.290%) to 109.474 m³/s (443.448%) for flow. For the assessment of weir modification, three different weir height were tested, namely scenario with existing weir height (1.5m), scenario with decrease of 0.1m weir height (1.4m) and scenario with decrease of 0.25m weir height (1.25m). Results for both 50 and 100-ARI show water level with a slight decrease in trend at upstream of weir and upstream of sg chini, but a slight increase at downstream of weir and downstream of Sg. Chini. However, both water level and flow increase at all locations. From the simulation, appropriate measures for flood and river management has been proposed to minimize the impact of flooding and at the same time to sustain the growth of lotus population at Tasik Chini without disrupting the navigational system along Sungai Chini.

LIST OF FIGURES

Figures	Title	Page
1	Tasik Chini Rizab Biosfera	3
2	The overall methodology of research	4
3	Topographic map of Sungai Chini	5
4	Average monthly rainfall in year 2010	6
5	Average monthly rainfall in year 2011	7
6	Average monthly rainfall in year 2012	7
7	Average monthly rainfall in year 2013	7
8	Feeder rivers of Tasik Chini	8
9	Landuse characteristics in 1994	9
10	Landuse characteristics in 2004	9
11	Comparison of Peak Discharge at J7 for various ARI	11
12	Comparison of Peak Discharge at J8 for various ARI	11
13	Proposed model extent	12
14	Existing Hydrodynamic Model	13
15	Location of proposed water level station	14
16	Water level logger	15
17	Location of Point 1 (discharge point of Tasik Chini)	15
18	Location of Point 2 (Navigational Gate upstream)	16
19	Location of Point 3 (Navigational Gate downstream)	16
20	Location of Point 4 (Kuala Sungai Chini)	17
21	Location of Point 6 (Sungai Pahang)	17
22	Water level data for Point 1	18
23	Water level data for Point 2	18
24	Water level data for Point 3	19
25	Water level data for Point 4	19
26	Water level data for Point 5	20
27	Water level data for Point 6	20
28	Comparison of water levels at various sampling location	21
29	Comparison of observed data and simulated data was done at upstream of weir located at Point 2	21

LIST OF FIGURES

Figures	Title	Page
30	Comparison of Water Level for Various ARIs at CH425 Weir Upstream for Scenario 1: Current (Landuse) and Baseline (Meteorology)	22
31	Comparison of Flow for Various ARIs at CH425 Weir Upstream for Scenario 1: Current (Landuse) and Baseline (Meteorology)	23
32	Comparison of Water Level for Various ARIs at CH425 Weir Downstream for Scenario 1: Current (Landuse) and Baseline (Meteorology)	23
33	Comparison of Flow for Various ARIs at CH425 Weir Downstream for Scenario 1: Current (Landuse) and Baseline (Meteorology)	23
34	Comparison of Water Level for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 1: Current (Landuse) and Baseline (Meteorology)	24
35	Comparison of Flow for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 1: Current (Landuse) and Baseline (Meteorology)	24
36	Comparison of Water Level for Various ARIs at CH425 Weir Upstream for Scenario 2: Current (Landuse) and Future (Meteorology)	25
37	Comparison of Flow for Various ARIs at CH425 Weir Upstream for Scenario 2: Current (Landuse) and Future (Meteorology)	25
38	Comparison of Water Level for Various ARIs at CH425 Weir Downstream for Scenario 2: Current (Landuse) and Future (Meteorology)	26
39	Comparison of Flow for Various ARIs at CH425 Weir Downstream for Scenario 2: Current (Landuse) and Future (Meteorology)	26
40	Comparison of Water Level for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 2: Current (Landuse) and Future (Meteorology)	26
41	Comparison of Flow for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 2: Current (Landuse) and Future (Meteorology)	27
42	Comparison of Water Level for Various ARIs at CH425 Weir Upstream for Scenario 3: Future (Landuse) and Baseline (Meteorology)	28
43	Comparison of Flow for Various ARIs at CH425 Weir Upstream for Scenario 3: Future (Landuse) and Baseline (Meteorology)	28
44	Comparison of Water Level for Various ARIs at CH425 Weir Downstream for Scenario 3: Future (Landuse) and Baseline (Meteorology)	28
45	Comparison of Flow for Various ARIs at CH425 Weir Downstream for Scenario 3: Future (Landuse) and Baseline (Meteorology)	29
46	Comparison of Water Level for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 3: Future (Landuse) and Baseline (Meteorology)	29
47	Comparison of Flow for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 3: Future (Landuse) and Baseline (Meteorology)	29

LIST OF FIGURES

Figures	Title	Page
48	Comparison of Water Level for Various ARIs at CH425 Weir Upstream for Scenario 4: Future (Landuse) and Future (Meteorology)	30
49	Comparison of Flow for Various ARIs at CH425 Weir Upstream for Scenario 4: Future (Landuse) and Future (Meteorology)	31
50	Comparison of Water Level for Various ARIs at CH425 Weir Downstream for Scenario 4: Future (Landuse) and Future (Meteorology)	31
51	Comparison of Flow for Various ARIs at CH425 Weir Downstream for Scenario 4: Future (Landuse) and Future (Meteorology)	31
52	Comparison of Water Level for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 4: Future (Landuse) and Future (Meteorology)	32
53	Comparison of Flow for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 4: Future (Landuse) and Future (Meteorology)	32
54	Comparison of water level on the impact of landuse change for 10-year ARI at CH425 Weir Upstream	34
55	Comparison of flow on the impact of landuse change for 10-year ARI at CH425 Weir Upstream	34
56	Comparison of water level on the impact of landuse change for 10-year ARI at CH425 Weir Downstream	34
57	Comparison of flow on the impact of landuse change for 10-year ARI at CH425 Weir Downstream	35
58	Comparison of water level on the impact of landuse change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	35
59	Comparison of flow on the impact of landuse change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	35
60	Comparison of water level on the impact of landuse change for 20-year ARI at CH425 Weir Upstream	36
61	Comparison of flow on the impact of landuse change for 20-year ARI at CH425 Weir Upstream	36
62	Comparison of water level on the impact of landuse change for 20-year ARI at CH425 Weir Downstream	37
63	Comparison of flow on the impact of landuse change for 20-year ARI at CH425 Weir Downstream	37
64	Comparison of water level on the impact of landuse change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	37

LIST OF FIGURES

Figures	Title	Page
65	Comparison of flow on the impact of landuse change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	38
66	Comparison of water level on the impact of landuse change for 25-year ARI at CH425 Weir Upstream	38
67	Comparison of flow on the impact of landuse change for 25-year ARI at CH425 Weir Upstream	39
68	Comparison of water level on the impact of landuse change for 25-year ARI at CH425 Weir Downstream	39
69	Comparison of flow on the impact of landuse change for 25-year ARI at CH425 Weir Downstream	39
70	Comparison of water level on the impact of landuse change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	40
71	Comparison of flow on the impact of landuse change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	40
72	Comparison of water level on the impact of landuse change for 50-year ARI at CH425 Weir Upstream	41
73	Comparison of flow on the impact of landuse change for 50-year ARI at CH425 Weir Upstream	41
74	Comparison of water level on the impact of landuse change for 50-year ARI at CH425 Weir Downstream	41
75	Comparison of flow on the impact of landuse change for 50-year ARI at CH425 Weir Downstream	42
76	Comparison of water level on the impact of landuse change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	42
77	Comparison of flow on the impact of landuse change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	42
78	Comparison of water level on the impact of landuse change for 100-year ARI at CH425 Weir Upstream	43
79	Comparison of flow on the impact of landuse change for 100-year ARI at CH425 Weir Upstream	43
80	Comparison of water level on the impact of landuse change for 100-year ARI at CH425 Weir Downstream	44
81	Comparison of flow on the impact of landuse change for 100-year ARI at CH425 Weir Downstream	44

LIST OF FIGURES

Figures	Title	Page
82	Comparison of water level on the impact of landuse change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	44
83	Comparison of flow on the impact of landuse change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	45
84	Comparison of water level on the impact of climate change for 10-year ARI at CH425 Weir Upstream	46
85	Comparison of flow on the impact of climate change for 10-year ARI at CH425 Weir Upstream	46
86	Comparison of water level on the impact of climate change for 10-year ARI at CH425 Weir Downstream	47
87	Comparison of flow on the impact of climate change for 10-year ARI at CH425 Weir Downstream	47
88	Comparison of water level on the impact of climate change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	47
89	Comparison of flow on the impact of climate change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	48
90	Comparison of water level on the impact of climate change for 20-year ARI at CH425 Weir Upstream	48
91	Comparison of flow on the impact of climate change for 20-year ARI at CH425 Weir Upstream	49
92	Comparison of water level on the impact of climate change for 20-year ARI at CH425 Weir Downstream	49
93	Comparison of flow on the impact of climate change for 20-year ARI at CH425 Weir Downstream	49
94	Comparison of flow on the impact of climate change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	50
95	Comparison of flow on the impact of climate change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	50
96	Comparison of water level on the impact of climate change for 25-year ARI at CH425 Weir Upstream	51
97	Comparison of flow on the impact of climate change for 25-year ARI at CH425 Weir Upstream	51
98	Comparison of flow on the impact of climate change for 25-year ARI at CH425 Weir Upstream	51

LIST OF FIGURES

Figures	Title	Page
99	Comparison of flow on the impact of climate change for 25-year ARI at CH425 Weir Downstream	52
100	Comparison of water level on the impact of climate change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini	52
101	Comparison of flow on the impact of climate change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	52
102	Comparison of water level on the impact of climate change for 50-year ARI at CH425 Weir Upstream	53
103	Comparison of flow on the impact of climate change for 50-year ARI at CH425 Weir Upstream	53
104	Comparison of water level on the impact of climate change for 50-year ARI at CH425 Weir Downstream	54
105	Comparison of flow on the impact of climate change for 50-year ARI at CH425 Weir Downstream	54
106	Comparison of water level on the impact of climate change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	54
107	Comparison of water level on the impact of climate change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	55
108	Comparison of water level on the impact of climate change for 100-year ARI at CH425 Weir Upstream	55
109	Comparison of flow on the impact of climate change for 100-year ARI at CH425 Weir Upstream	56
110	Comparison of water level on the impact of climate change for 100-year ARI at CH425 Weir Downstream	56
111	Comparison of flow on the impact of climate change for 100-year ARI at CH425 Weir Downstream	56
112	Comparison of water level on the impact of climate change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	57
113	Comparison of flow on the impact of climate change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	57
114	Comparison of water level on the combination of the impact of landuse and climate change for 10-year ARI at CH425 Weir Upstream	59
115	Comparison of flow on the combination of the impact of landuse and climate change for 10-year ARI at CH425 Weir Upstream	59

LIST OF FIGURES

Figures	Title	Page
116	Comparison of water level on the combination of the impact of landuse and climate change for 10-year ARI at CH425 Weir Downstream	59
117	Comparison of flow on the combination of the impact of landuse and climate change for 10-year ARI at CH425 Weir Downstream	60
118	Comparison of water level on the combination of the impact of landuse and climate change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	60
119	Comparison of flow on the combination of the impact of landuse and climate change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	60
120	Comparison of water level on the combination of the impact of landuse and climate change for 20-year ARI at CH425 Weir Upstream	61
121	Comparison of flow on the combination of the impact of landuse and climate change for 20-year ARI at CH425 Weir Upstream	62
122	Comparison of water level on the combination of the impact of landuse and climate change for 20-year ARI at CH425 Weir Downstream	62
123	Comparison of flow on the combination of the impact of landuse and climate change for 20-year ARI at CH425 Weir Downstream	62
124	Comparison of water level on the combination of the impact of landuse and climate change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	63
125	Comparison of flow on the combination of the impact of landuse and climate change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	63
126	Comparison of water level on the combination of the impact of landuse and climate change for 25-year ARI at CH425 Weir Upstream	64
127	Comparison of flow on the combination of the impact of landuse and climate change for 25-year ARI at CH425 Weir Upstream	65
128	Comparison of water level on the combination of the impact of landuse and climate change for 25-year ARI at CH425 Weir Downstream	65
129	Comparison of flow on the combination of the impact of landuse and climate change for 25-year ARI at CH425 Weir Downstream	65

LIST OF FIGURES

Figures	Title	Page
130	Comparison of water level on the combination of the impact of landuse and climate change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	66
131	Comparison of flow on the combination of the impact of landuse and climate change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	66
132	Comparison of water level on the combination of the impact of landuse and climate change for 50-year ARI at CH425 Weir Upstream	67
133	Comparison of flow on the combination of the impact of landuse and climate change for 50-year ARI at CH425 Weir Upstream	68
134	Comparison of water level on the combination of the impact of landuse and climate change for 50-year ARI at CH425 Weir Downstream	68
135	Comparison of flow on the combination of the impact of landuse and climate change for 50-year ARI at CH425 Weir Downstream	68
136	Comparison of water level on the combination of the impact of landuse and climate change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	69
137	Comparison of flow on the combination of the impact of landuse and climate change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	69
138	Comparison of water level on the combination of the impact of landuse and climate change for 100-year ARI at CH425 Weir Upstream	70
139	Comparison of flow on the combination of the impact of landuse and climate change for 100-year ARI at CH425 Weir Upstream	71
140	Comparison of water level on the combination of the impact of landuse and climate change for 100-year ARI at CH425 Weir Downstream	71
141	Comparison of flow on the combination of the impact of landuse and climate change for 100-year ARI at CH425 Weir Downstream	71
142	Comparison of water level on the combination of the impact of landuse and climate change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	72
143	Comparison of flow on the combination of the impact of landuse and climate change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)	72

LIST OF FIGURES

Figures	Title	Page
144	Comparison of water level for different weir's height for Current Landuse and Baseline (Meteorology) for 50-year ARI	74
145	Comparison of flow for different weir's height for Current Landuse and Baseline (Meteorology) for 50-year ARI	75
146	Comparison of water level for different weir's height for Current Landuse and Future (Meteorology) for 50-year ARI	75
147	Comparison of flow for different weir's height for Current Landuse and Future (Meteorology) for 50-year ARI	76
148	Comparison of water level for different weir's height for Future Landuse and Baseline (Meteorology) for 50-year ARI	77
149	Comparison of flow for different weir's height for Future Landuse and Baseline (Meteorology) for 50-year ARI	77
150	Comparison of water level for different weir's height for Future Landuse and Future (Meteorology) for 50-year ARI	78
151	Comparison of flow for different weir's height for Future Landuse and Future (Meteorology) for 50-year ARI	79
152	Comparison of water level for different weir's height for Current Landuse and Baseline (Meteorology) for 100-year ARI	79
153	Comparison of flow for different weir's height for Current Landuse and Baseline (Meteorology) for 100-year ARI	80
154	Comparison of water level for different weir's height for Current Landuse and Future (Meteorology) for 100-year ARI	81
155	Comparison of flow for different weir's height for Current Landuse and Future (Meteorology) for 100-year ARI	81
156	Comparison of water level for different weir's height for Future Landuse and Baseline (Meteorology) for 100-year ARI	82
157	Comparison of flow for different weir's height for Future Landuse and Baseline (Meteorology) for 100-year ARI	83
158	Comparison of water level for different weir's height for Future Landuse and Future (Meteorology) for 100-year ARI	83
159	Comparison of flow for different weir's height for Future Landuse and Future (Meteorology) for 100-year ARI	84

LIST OF FIGURES

Figures	Title	Page
160	Recommended measures under Option 1	87
161	Recommended measures under Option 2	88
162	River Improvement for Sg Chini (From CH65 to CH1950)	89
163	River Improvement for Sg Gumum (From Sg Gumum CH 600- CH665)	89
164	River Improvement for Sg Jerangking (From Sg Jerangking CH175 to CH28)	90
165	River Improvement for Sg Kura-Kura (From Sg Kura-Kura CH800 to CH665)	90
166	River Improvement for Sg Jemberai (From Sg Jemberai CH500 to CH130)	90
167	River Improvement for Sg Melai (From Sg Melai CH796 to CH330)	91
168	River Improvement for Sg Perupok (From Sg Perupok CH3428 to CH360)	91
169	River Improvement for Sg Paya Merapuh (From Sg Paya Merapuh CH4939 to CH360)	91

LIST OF TABLES

Table	Title	Page
1	List of rainfall stations	5
2	List of water level station	6
3	Average rainfall data for 2010 to 2013	6
4	Information on surveyed feeder river of Tasik Chini	8
5	Comparison of Peak Discharge at J7 for various ARI	10
6	Comparison of Peak Discharge at J8 for various ARI	10
7	Maximum water level for various ARIs for Scenario 1: Current (Landuse) and Baseline (Meteorology)	22
8	Maximum flow for various ARIs for Scenario 1: Current (Landuse) and Baseline (Meteorology)	22
9	Maximum water level for various ARIs for Scenario 2: Current (Landuse) and Future (Meteorology)	24
10	Maximum flow for various ARIs for Scenario 2: Current (Landuse) and Future (Meteorology)	25
11	Maximum water level for various ARIs for Scenario 3: Future (Landuse) and Baseline (Meteorology)	27
12	Maximum flow for various ARIs for Scenario 3: Future (Landuse) and Baseline (Meteorology)	27
13	Maximum water level for various ARIs for Scenario 4: Future (Landuse) and Future (Meteorology)	30
14	Maximum flow for various ARIs for Scenario 4: Future (Landuse) and Future (Meteorology)	30
15	Assessment on the impact of landuse change for 10-year ARI	33
16	Assessment on the impact of landuse change for 20-year ARI	36
17	Assessment on the impact of landuse change for 25-year ARI	38
18	Assessment on the impact of landuse change for 50-year ARI	40
19	Assessment on the impact of landuse change for 100-year ARI	43
20	Assessment on the impact of climate change for 10-year ARI	46
21	Assessment on the impact of climate change for 20-year ARI	48
22	Assessment on the impact of climate change for 25-year ARI	50
23	Assessment on the impact of climate change for 50-year ARI	53
24	Assessment on the impact of climate change for ARI 100-year	55
25	Assessment on the impact of landuse and climate change for 10-year ARI	58
26	Assessment on the impact of landuse and climate change for 20-year ARI	61
27	Assessment on the impact of landuse and climate change for 25-year ARI	64

LIST OF TABLES

Table	Title	Page
28	Assessment on the impact of landuse and climate change for 50-year ARI	67
29	Assessment on the impact of landuse and climate change for 100-year ARI	70
30	Assessment of the water level changes for different weir's height for Current Landuse and Baseline (Meteorology) for 50-year ARI	74
31	Assessment of the flow changes for different weir's height for Current Landuse and Baseline (Meteorology) for 50-year ARI	74
32	Assessment of the water level changes for different weir's height for Current Landuse and Future (Meteorology) for 50-year ARI	75
33	Assessment of the flow changes for different weir's height for Current Landuse and Future (Meteorology) for 50-year ARI	76
34	Assessment of the water level changes for different weir's height for Future Landuse and Baseline (Meteorology) for 50-year ARI	76
35	Assessment of the flow changes for different weir's height for Future Landuse and Baseline (Meteorology) for 50-year ARI	77
36	Assessment of the water level changes for different weir's height for Future Landuse and Future (Meteorology) for 50-year ARI	78
37	Assessment of the flow changes for different weir's height for Future Landuse and Future (Meteorology) for 50-year ARI	78
38	Assessment of the water level changes for different weir's height for Current Landuse and Baseline (Meteorology) for 100-year ARI	79
39	Assessment of the flow changes for different weir's height for Current Landuse and Baseline (Meteorology) for 100-year ARI	80
40	Assessment of the water level changes for different weir's height for Current Landuse and Future (Meteorology) for 100-year ARI	80
41	Assessment of the flow changes for different weir's height for Current Landuse and Future (Meteorology) for 100-year ARI	81
42	Assessment of the water level changes for different weir's height for Future Landuse and Baseline (Meteorology) for 100-year ARI	82
43	Assessment of the flow changes for different weir's height for Future Landuse and Baseline (Meteorology) for 100-year ARI	82
44	Assessment of the water level changes for different weir's height for Future Landuse and Future (Meteorology) for 100-year ARI	83
45	Assessment of the flow changes for different weir's height for Future Landuse and Future (Meteorology) for 100-year ARI	84
46	Estimated costing for the recommended flood mitigation measures	89

1.0 INTRODUCTION

1.1 Background

Tasik Chini is located near the Pahang River in the Pahang state. It is the land of Orang Asli typically known as Orang Jakun. The community of Orang Jakun was dependently on the ecosystem of Tasik Chini for their daily life. Tasik Chini once was famous because of its biological diversity. A study from Malaysian Nature Society (1992) found that there were 309 species of plants including aquatic plants, 92 species of birds and 144 species of aquatic life in the area of Tasik Chini.

The lake was considered as Alluvial Riparian Wetlands System (Alluvial Riparian Swamp System); Lakes affected by sediment formed by runoff containing material erosion, transport and deposition of the river, creating a landform of river floodplains and deltas. The lake is categorized as type of lake that having the most vulnerable ecosystem. Tasik Chini originally contains a variety of flora and fauna as well as some type of natural origin for this region (indigenous). Some of them are rarely found and vulnerable or are facing extinction.

This area also can act as a water reservoir monsoon (monsoonal water storage site) with the extensive wetlands that act as a barrier and a natural water storage that can reduce and control the level, speed and frequency of flooding. Due to the development of Tasik Chini, the environment has greatly changed the topography and the pattern of land use in the area which contributes to the hydrological imbalance and altering the entire ecosystem of the lake.

Tasik Chini's condition became worse when a small dam or weir was built in 1995 to retain the lake's water for tourism purposes (Ahmad *et al.*, 2004). These caused the water level of the lake has risen and water movement to become less dynamic (Suhaimi-Othman *et al.*, 2007). Fish activities were also affected and water current became unstable, although the lake water was defined as safe for recreational purposes (Ahmad *et al.*, 2004). The content of contaminants were also increased, including certain metals in lake water is not compatible with the original life of the lake led to the extinction of certain species of fish, including the lotus plant, which became the main attractions and the identity of the lake. Thus, there is an urgent need for a concerted research in Tasik Chini.

1.2 Research Objectives

The objectives of the proposed project are as follows:

- i) To develop a hydrodynamic model for Sungai Chini, Pahang using InfoWorks Catchment Modelling (ICM) based on the calibrated and verified hydrological model using HEC-HMS, and
- ii) To assess the impact of the existing weir under baseline and future scenario for various return periods (10-, 20-, 25-, 50- and 100-year Average Recurrence Interval (ARI)) to the hydrodynamic of Sg. Chini

1.3 Research Scopes

The scopes of work will include the following:-

- (a) Collate and collect relevant data (HEC-HMS time series results for discharge vs time for various ARI at the intersection of Sg. Chini, Sg. Chini Cross-section data, weir cross-section, bathymetry (evaluation of existing data), digitize the data and incorporate them into the database using the platform of Geographic Information System (GIS))
- (b) Carry out data cleaning, processing and analyses for all data acquired
- (c) Development of Sg. Chini hydrodynamic modelling by applying results from calibrated and verified hydrologic model from HEC-HMS and hydraulic analyses
- (d) Calibration and verification of hydraulic model based on available data
Assessment on the impact of existing weir under baseline and future scenario for various return periods (10-, 20-, 25-, 50- and 100-year ARI)
- (e) Reporting

1.4 Research Site

Tasik Chini is the second largest natural freshwater lake in Malaysia (JPS, 2011). Tasik Chini is located in the southeast region of Pahang, Malaysia. The lake system lies at 3°15'40"N and 102° 45'40"E and comprises 12 open water bodies. The water body is approximately 202 hectares and surrounded by 7.0 km² of freshwater marsh and swamp forest around the lake. The catchments area is about 49.8 km² consists of 12 small lakes and receiving water flow from several river tributaries namely Sg. Datang, Sg. Gumum, Sg. Perupok and Sg. Melai (JAS Pahang, 2011). Flow from Tasik Chini will then discharge into Sungai Chini before

connecting with Sg. Pahang. The total length of Sg. Chini is at 4.8 km and intersects at km 84 of Sg. Pahang flowing towards South China Sea.

Tasik Chini has a humid tropical climate with relative humidity greater than 80%. It is influenced by two monsoon periods, characterized by bimodal pattern: southwest and northeast monsoons bringing an evenly annual rainfall 2300mm throughout the year. The annual average temperature is $\pm 28^{\circ}\text{C}$ and the wind velocity is below 0.5m/s. Figure 1 below shows the location of research site.

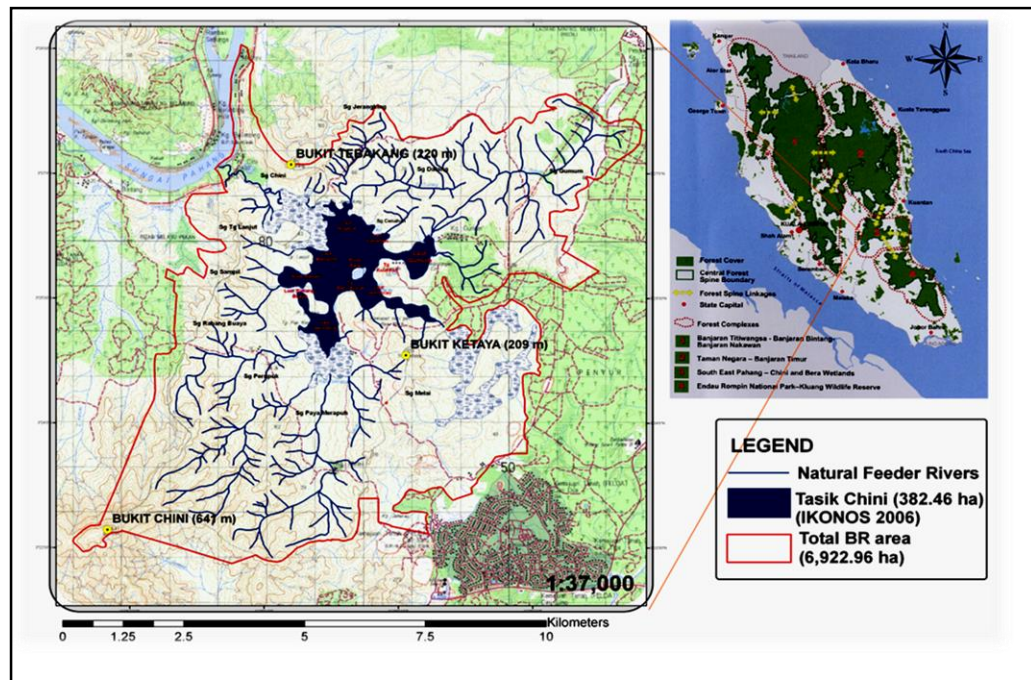


Figure 1: Tasik Chini Rizab Biosfera (UKM, 2009)

2.0 RESEARCH METHODOLOGY

The methodology of the study is illustrated by using a flowchart. Basically, the breakdowns of the methodology adopted for the research site are as in Figure 2.

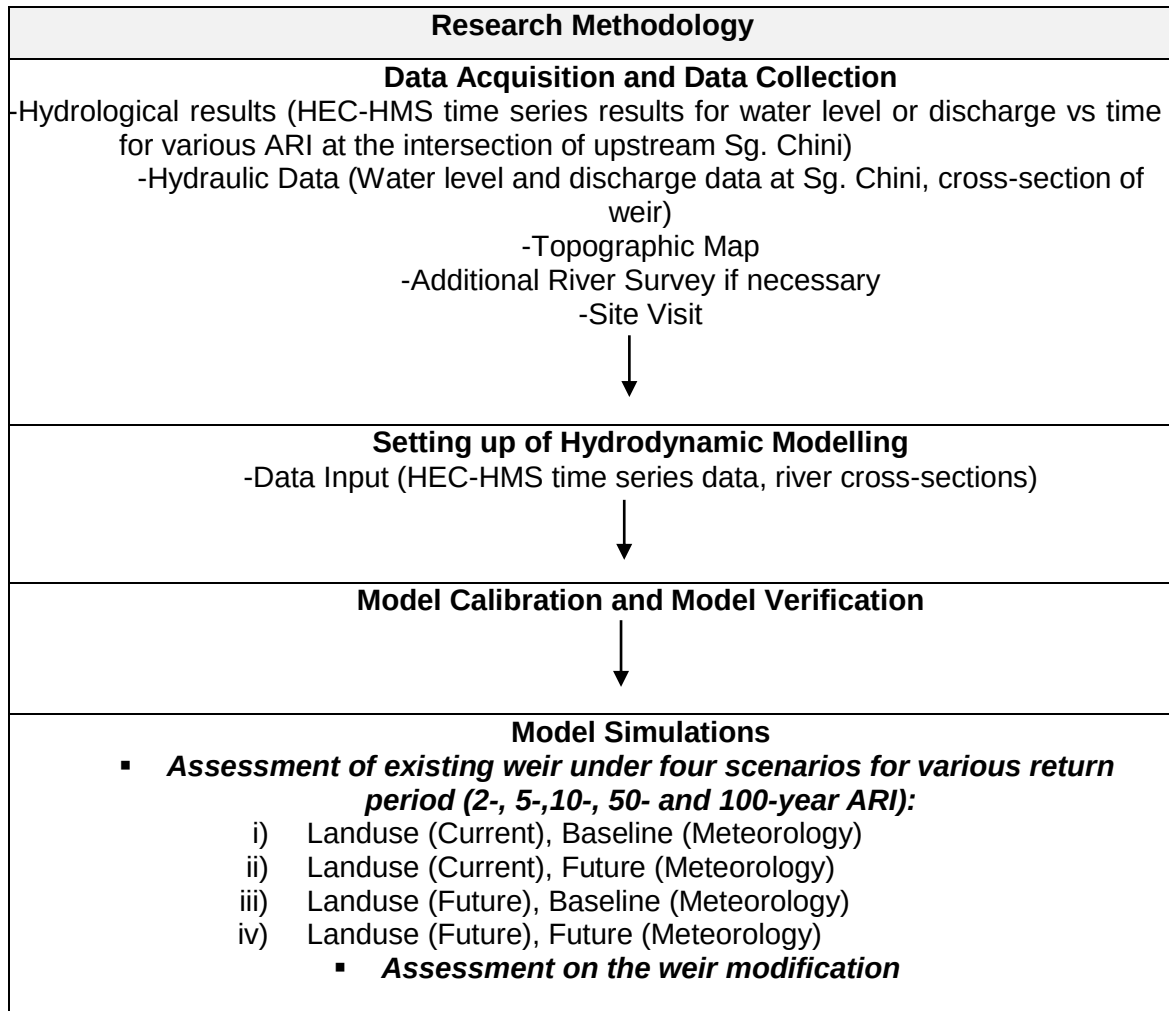


Figure 2: The overall methodology of research

3.0 DATA ACQUISITION AND DATA COLLECTION

3.1 Topographic Map

Tasik Chini is surrounded by variously vegetated low hills and undulating lands which constitute the watershed of the region. There are three hill areas surrounding the Tasik; namely, (1) Bt. Ketaya (209m) located at the southeast; (2) Bt. Tebakang (210m) at the north and (3) Bt. Chini (641m) at the southeast. Figure 3 below shows the topographic map of Sungai Chini.



Figure 3 : Topographic map of Sungai Chini

3.2 Hydrological Stations

A total of twelve (12) rainfall stations and one (1) water level station are available within the study area. The list of rainfall stations is shown in Table 1 and the list of water level station is shown in Table 2. The average monthly rainfall data for year 2010 to 2013 is shown as in Table 3 and Figures 4 to 7.

Table 1: List of Rainfall Stations

No	Station	Station no	District	River	River Basin	Latitude	Longitude
1	Bkt. Ibam	3129177	Pekan	Sg. Jeram	Rompin	3°10'05"	102°58'35"
2	Sg. Cabang Kanan	3228174	Rompin	Sg. Cabang	Rompin	3°17'55"	102°49'20"
3	Kg. Unchang	3231163	Pekan	Sg. Bebar	Bebar	3°17'15"	103°11'20"
4	Kg. Batu Gong	3330109	Pekan	Sg. Mentiga	Pahang	3°23'25"	103°01'35"
5	Kg. Salong	3429096	Pekan	Sg. Pahang	Pahang	3°29'10"	102°56'00"
6	Kg. Paya Membang	3430097	Pekan	Sg. Pahang	Pahang	3°27'15"	103°02'05"
7	Kg. Serambi	3431099	Pekan	Sg. Pahang	Sg. Pahang	3°29'50"	103°08'20"

8	Lubok Paku	3527092	Pekan	Sg. Pahang	Pahang	3°31'10"	102°46'40"
9	Kg. Temai Hilir	3532101	Pekan	Sg. Pahang	Pahang	3°32'10"	103°14'50"
10	Pintu Kawalan Paya Kertam	3628001	Temerloh	Sg. Luit	Pahang	3°38'10"	102°51'20"
11	Kg. Pulau Manis	3631001	Kuantan	Sg. Belat	Kuantan	3°39'10"	103°07'10"
12	Sg. Jerik	3726073	Maran	Sg. Jerik	Pahang	3°46'50"	102°38'35"

Table 2 : List of water level station

No	Station	Station no	District	River	River basin
1	Kuala Sg. Chini	3428401	Pekan	Sg. Chini	Sg. Pahang

Table 3 : Average rainfall data for 2010 to 2013

Month/Year	2010	2011	2012	2013
Jan	101.9	407.6	114.5	113.625
Feb	32.1	19.7	140.7	334.25
Mar	83	432.2	164.8	31.75
Apr	181.4	114.9	176.3	177.75
May	136.5	119.8	171	254.25
Jun	253.6	132.1	66.7	115.75
Jul	246.7	85.6	184.8	85.8
Aug	111.1	133.7	180.1	146.3
Sep	199.6	226.2	198.7	167.4
Oct	162.9	209.8	174.7	212.2
Nov	201.68	316.5	297.875	199
Dis	311.32	468.1	435.875	27
Average =	168.4833	222.1833	192.1708	155.4229

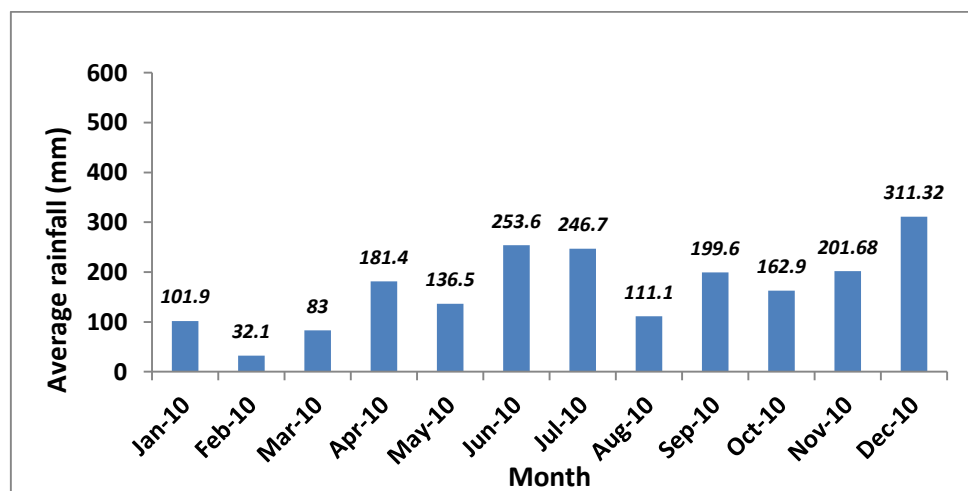


Figure 4: Average monthly rainfall in year 2010

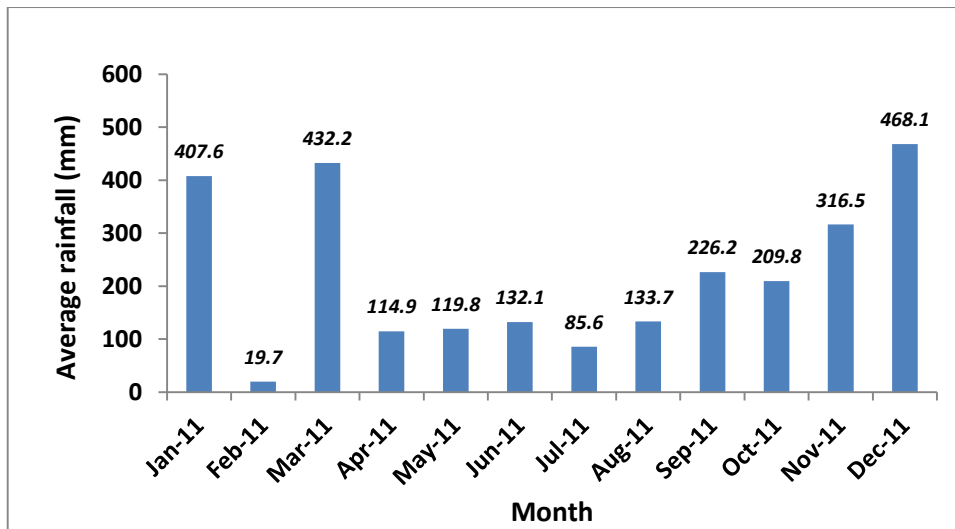


Figure 5 : Average monthly rainfall in year 2011

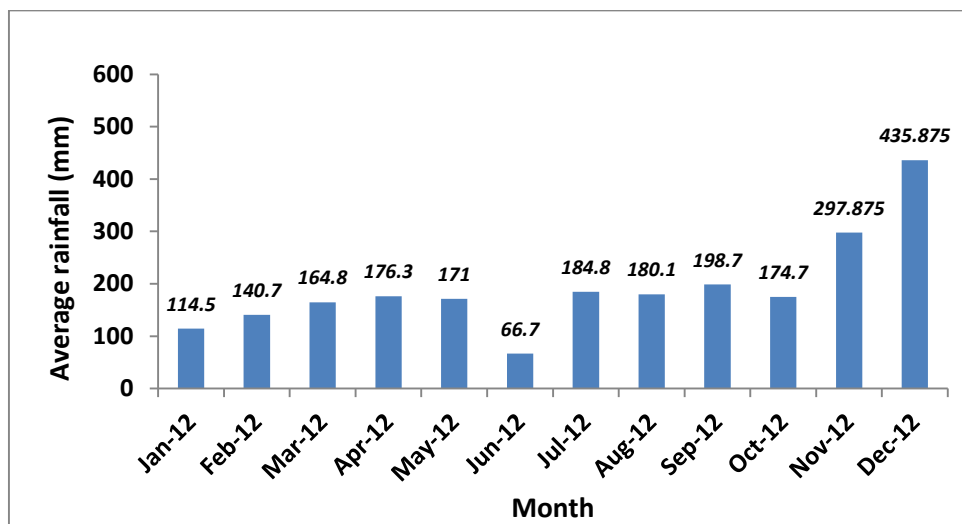


Figure 6: Average monthly rainfall in year 2012

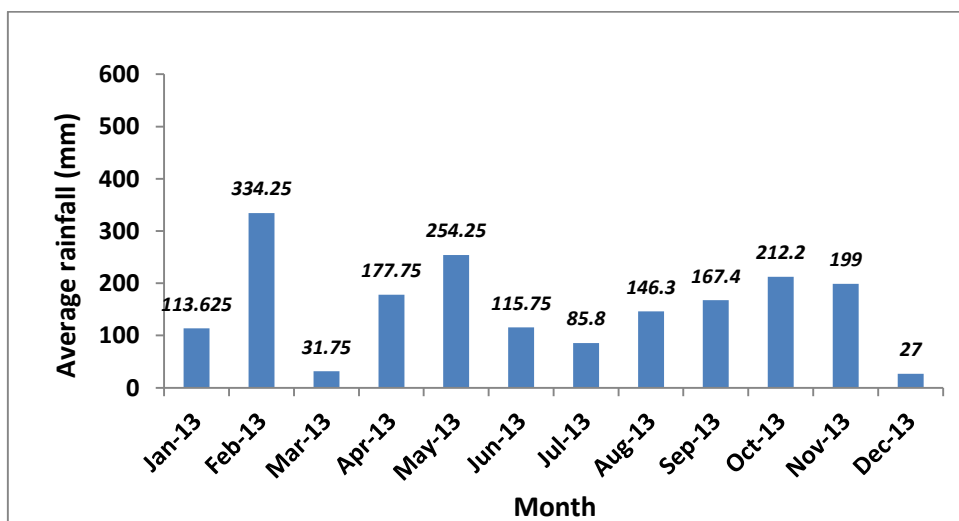


Figure 7: Average monthly rainfall in year 2013

3.3 River System

There are 7 main feeder rivers flowing into Tasik Chini namely Sungai Melai, Sungai Paya Merapuh, Sungai Perupok, Sungai Kura-Kura, Sungai Gumum, Sungai Jerangking and Sungai Jemberai. Streamflow for each feeder rivers is relatively low, recorded from 0.0042 to 0.9083 m³/s or an average of 0.1674 m³/s (Gasim et al, 2006). Apart from the feeder rivers, Sungai Chini and Sungai Pahang are as well modelled. Information on the surveyed rivers is tabulated as in Table 4.

Table 4: Information on surveyed rivers of Tasik Chini

No	River System	River Length (m)	River Width (m)	Chainage	Total cross-sections	Interval (m)
1	Sungai Melai	1800	8-36	00-1800	10	200
2	Sungai Paya Merapuh	5400	3-7	00-5400	27	200
3	Sungai Perupok	4200	5-13	00-4200	22	200
4	Sungai Kura-Kura	800	4-5	00-800	5	200
5	Sungai Gumum	2200	3-5	00-2200	12	200
6	Sungai Jerangking	800	3-4	00-800	5	200
7	Sungai Jemberai	500	4-7	00-500	4	200
8	Sungai Chini	4000	10-17	00-4000	60	25-200
9	Sungai Pahang	6000	420-557 (Upstream) 420-819 (Downstream)	00-3000 (Upstream) 00-3000 (Downstream)	6	1000

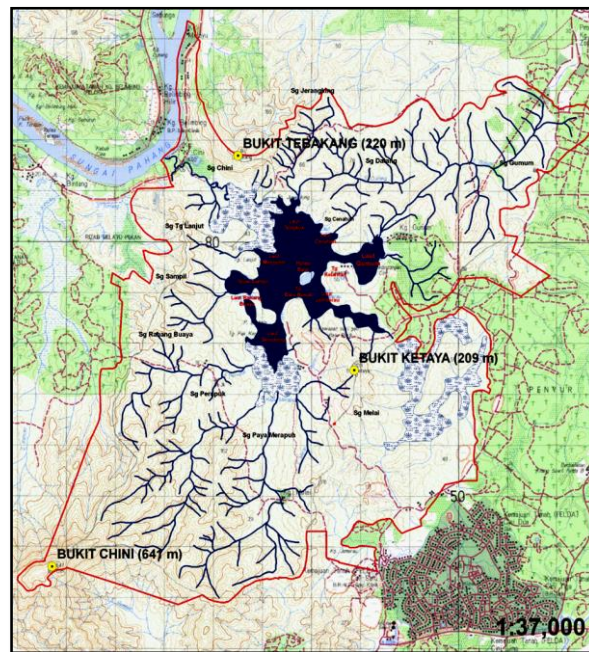


Figure 8: Feeder rivers of Tasik Chini

3.4 Land Use Map

The catchment of Tasik Chini is dominated by forest with almost 50% of the area covered with forest. Figure 9 and 10 below shows the landuse characteristics of Chini area for year 1994 and 2004 respectively.

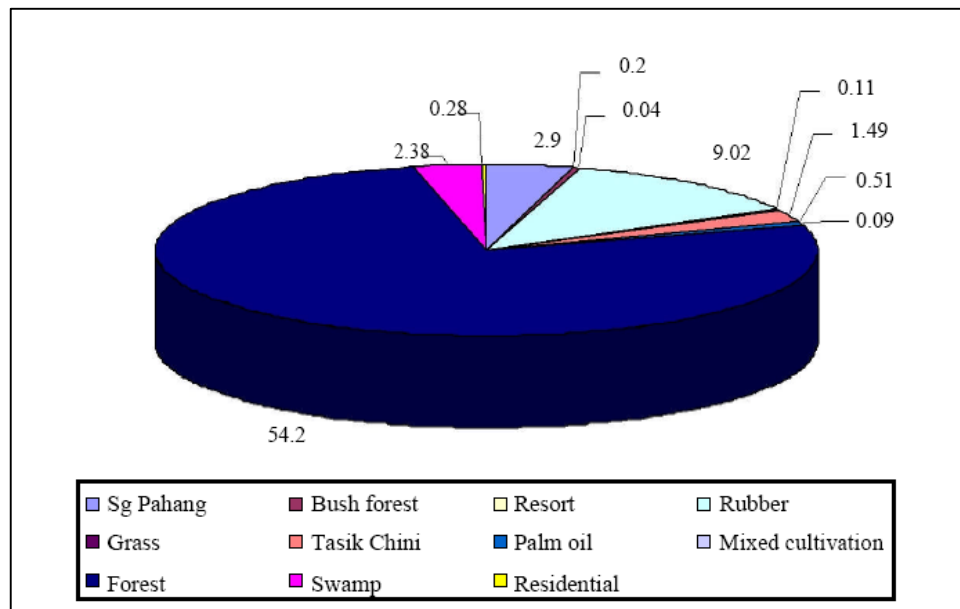


Figure 9: Landuse characteristics in 1994 (Gasim et. al, 2006)

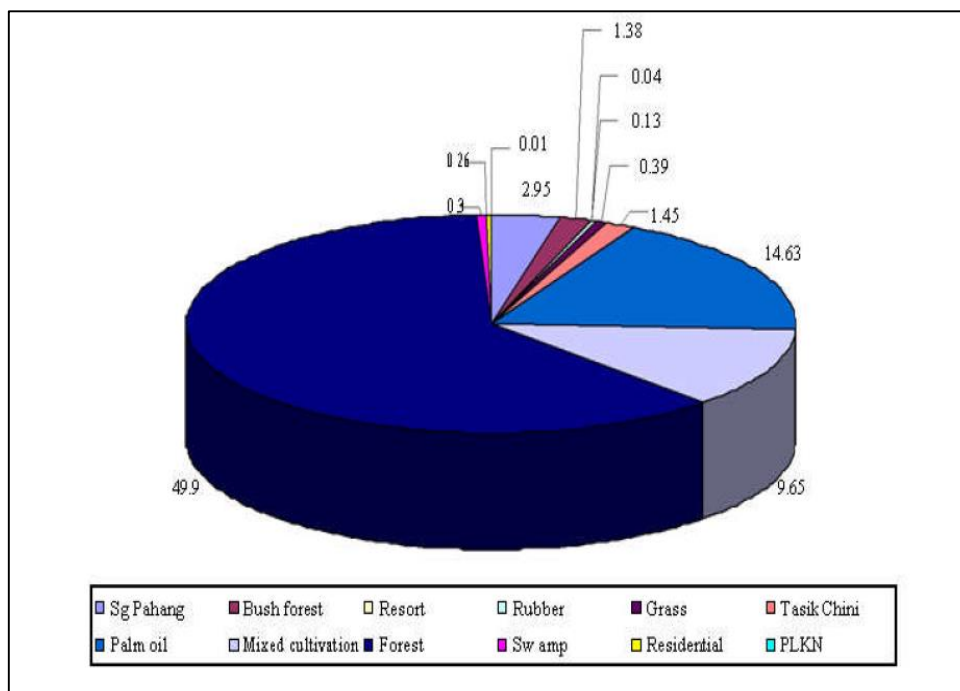


Figure 10: Landuse characteristics in 2004 (Gasim et.al, 2006)

4.0 DATA PROCESSING

4.1 Hydrological Analysis

Rainfall and water level data are necessary to serve as an input in the numerical model for the simulation and calibration purposes. Hydrological results from HEC-HMS are applied for this hydrodynamic modelling (NAHRIM, 2015). The example of peak discharge for J7 and J8 are tabulated in Table 5 and Table 6 respectively. J7 is denoted as an inflow from all the feeder rivers flowing into Tasik Chini while J8 is denoted as an outflow from Tasik Chini into Sungai Pahang. Figures 12 and 13 show the comparison of peak discharge for various ARI for J7 and J8 respectively.

Table 5: Comparison of Peak Discharge at J7 for various ARI

ARI	Peak Discharge (m ³ /s)			
	Current Baseline	Current Future	Future Baseline	Future Future
10	68.5	128	70.6	131.1
20	86.5	166.6	89	170.1
25	93.2	186.9	95.8	190.7
50	116.4	238.4	119.3	242.6
100	144.2	288.3	147.5	292.8

Table 6 : Comparison of Peak Discharge at J8 for various ARI

ARI	Peak Discharge (m ³ /s)			
	Current Baseline	Current Future	Future Baseline	Future Future
10	69.5	129.7	72.2	133.5
20	87.7	168.7	90.8	173
25	94.4	189.2	97.6	193.7
50	117.9	241.4	121.5	246.3
100	146.1	291.8	150.1	297.1

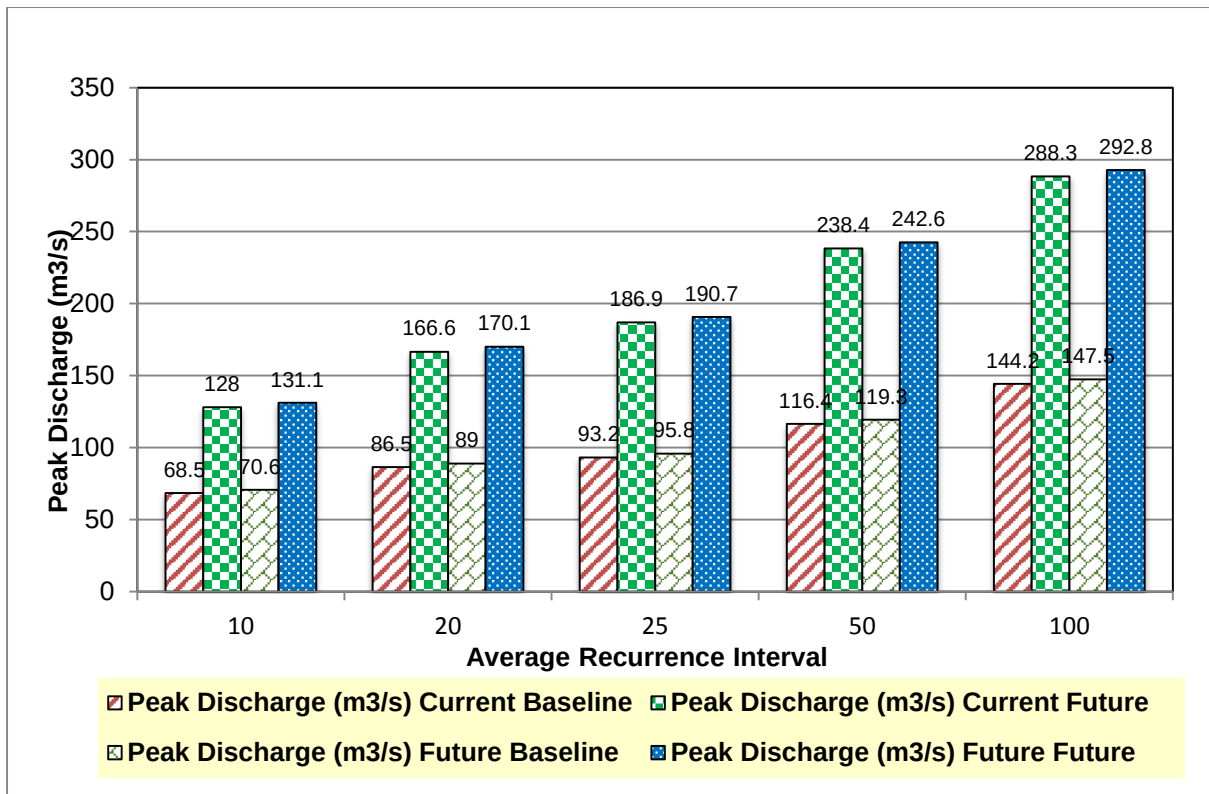


Figure 11: Comparison of Peak Discharge at J7 for various ARI

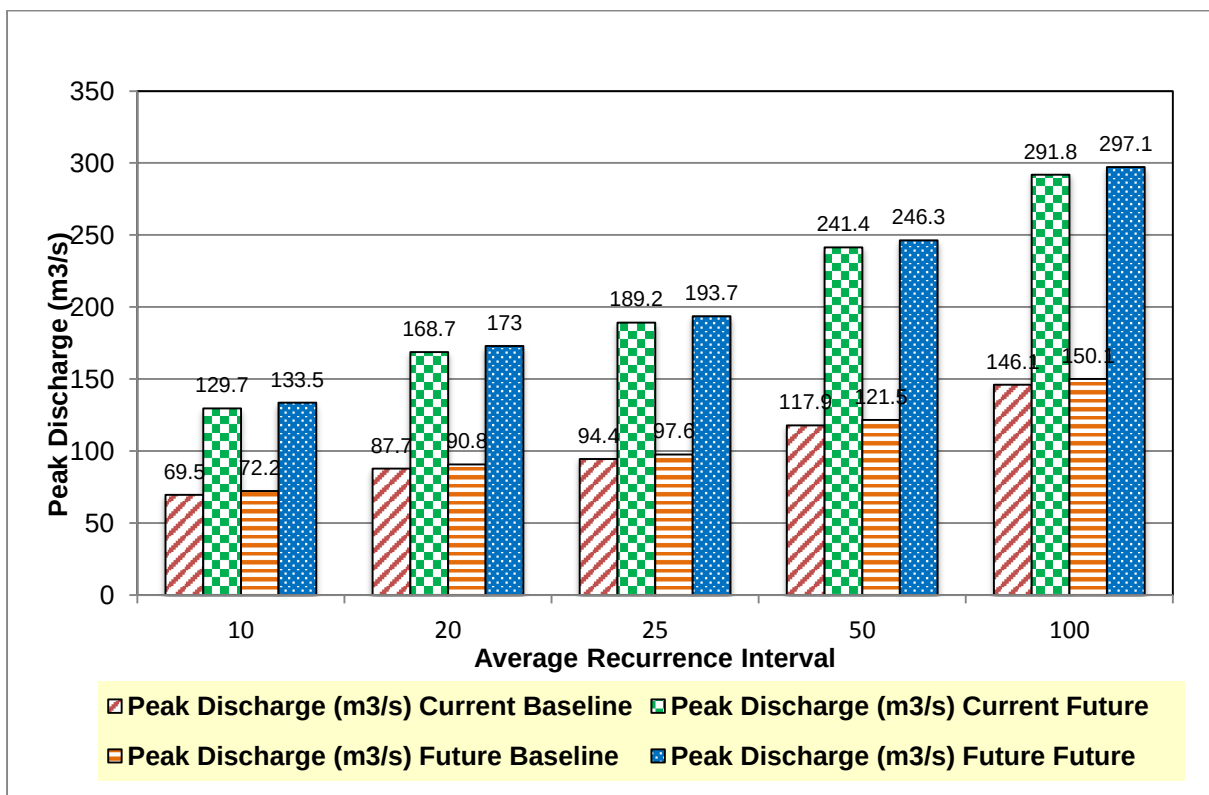


Figure 12: Comparison of Peak Discharge at J8 for various ARI

5.0 MODEL SET-UP

5.1 Hydrodynamic Software

Infoworks Integrated Catchment modelling (ICM) is a hydraulic modelling package that allows flows in drainage systems and rivers to be simulated in the same interface. It has an intuitive interface and rich functionality that allows rapid model build and simulation run time.

Infoworks ICM has the ability to model the complete above and below ground drainage system (natural and engineered) in one model and also 1D and 2D calculations standard throughout the package.

5.2 River Hydraulic Model

For this particular project, the model covered all the 7 feeder rivers of Tasik Chini until the confluence of Sg. Pahang as in Figures 13 and 14. A total of 151 river sections were built in the model ranging from 25 metres to 1 kilometres interval. Refer to Table 4.

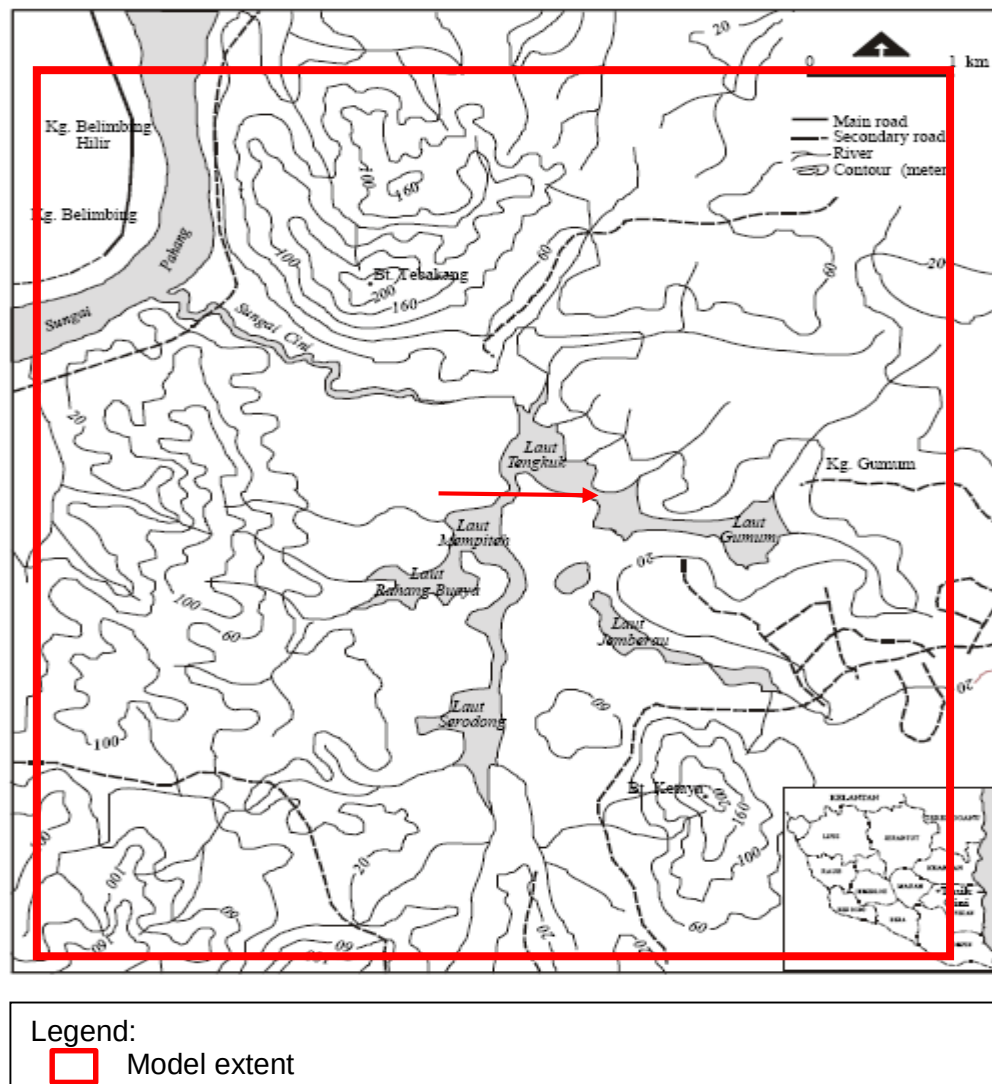


Figure 13: Model extent

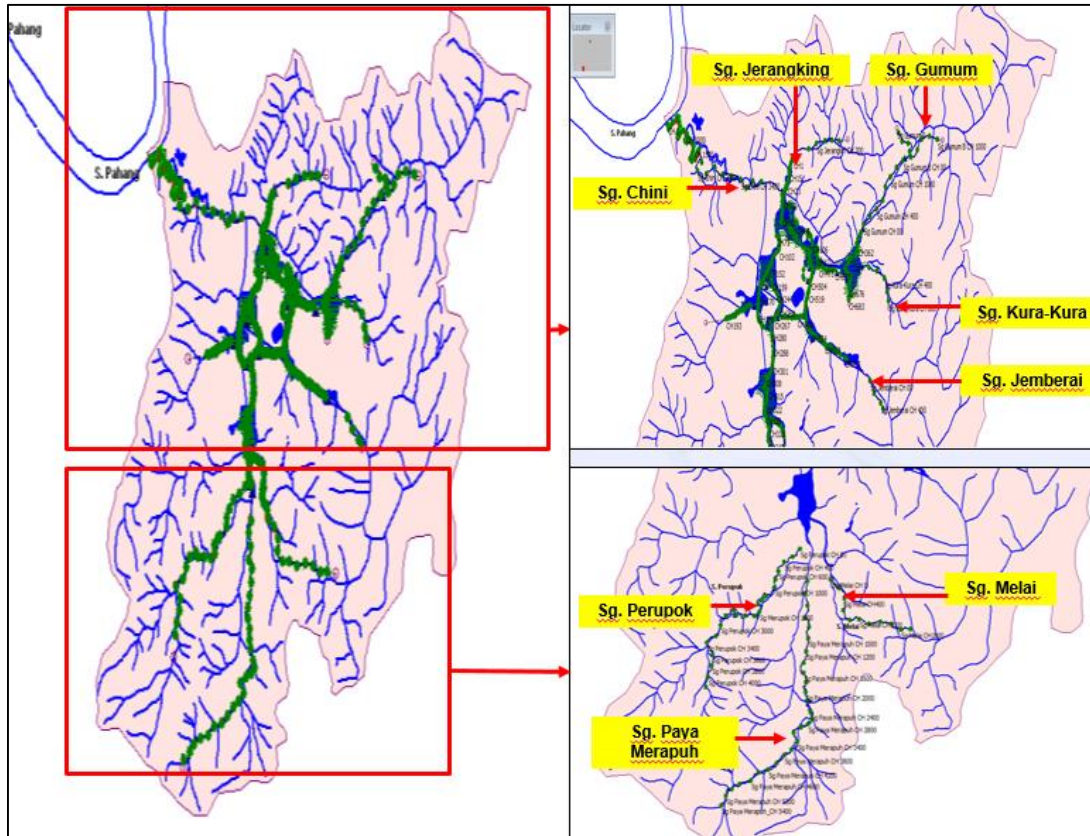


Figure 14: Existing Hydrodynamic Model

5.3 Model Calibration and Verification

Calibrated and validated hydrology model using HEC-HMS were used as the input data for this hydrodynamic model (NAHRIM, 2014). For hydrodynamic model, a scheduled sampling work has been carried out to collect water level data at site for the model calibration and verification purposes. Six water level loggers denoted as P1 to P6 as in Figure 15 were installed for a durations of 2 weeks from 28 October to 11 November 2014 with 15 minutes interval. These installed water level loggers, as shown in Figure 16 shows the Aqua Logger 520 pressure sensor model developed by Aquatec Group, United Kingdom. P1 to P4 is located along Sungai Chini while P5 and P6 are along Sungai Pahang. The location of sampling points are as depicted in Figure 17 to 21. Water level data captured from the six locations were shown from Figure 22 to 27. Figure 28 shows the comparison of water levels at various sampling location.

A comparison of observed data and simulated data was done at upstream of weir located at P2. Figure 29 shows the comparison at P2. The results show that the differences of water level is 2.7 cm with the overall accuracy of 90%. There is a constraint in the model calibration as only one location were compared due to the limitation of data. However, the model can still be applied for further model simulation.

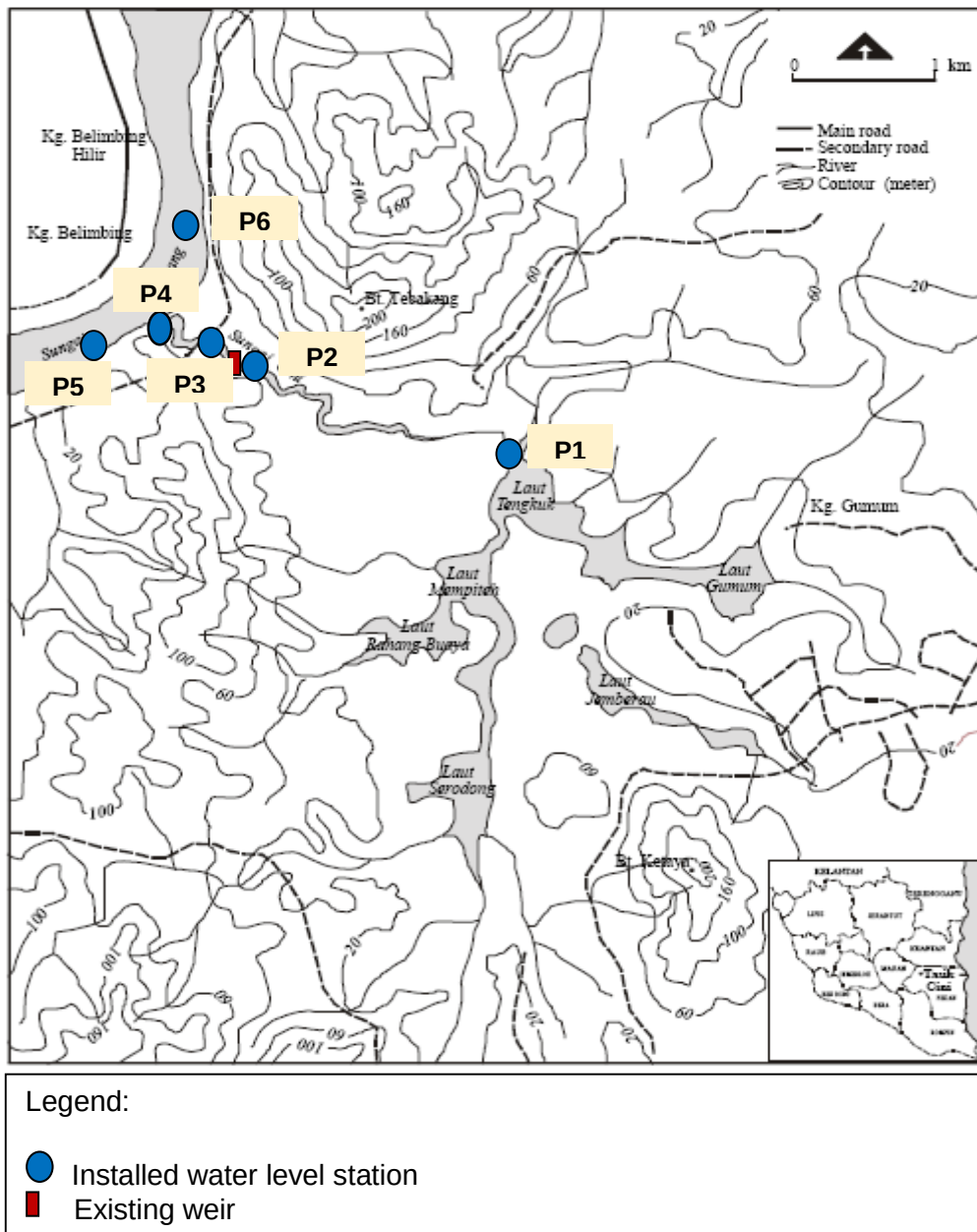


Figure 15: Location of water level station installed



Figure 16: Water level logger

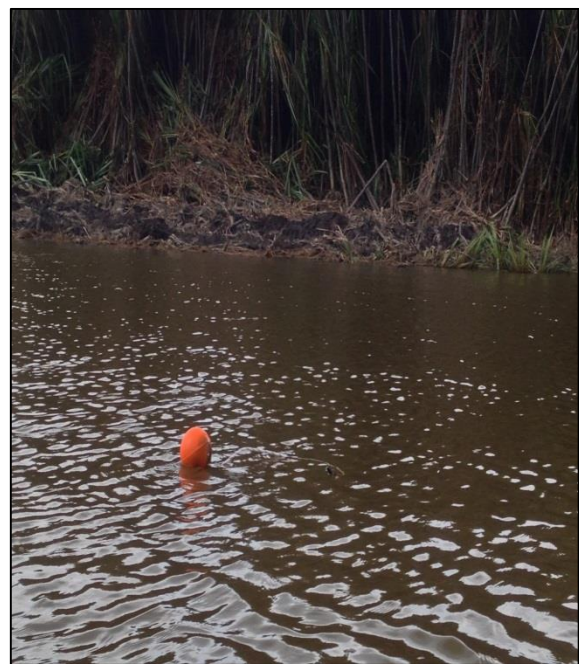


Figure 17: Location of Point 1 (Discharge point of Tasik Chini)

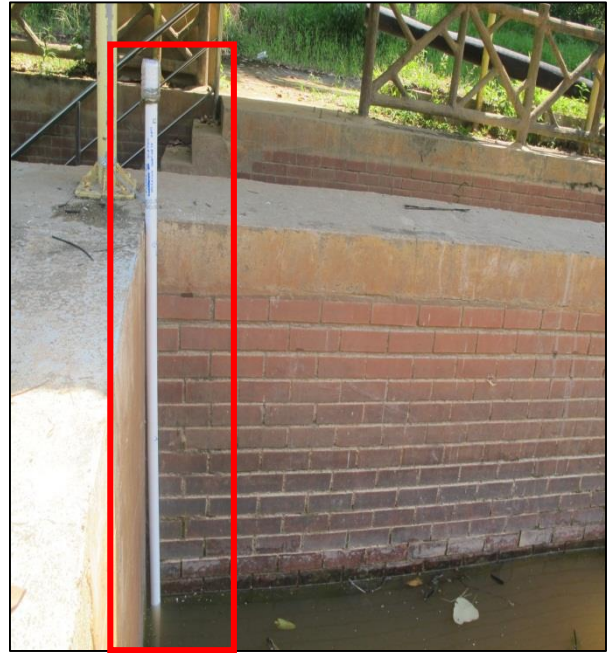


Figure 18: Location of Point 2 (Navigational Gate upstream)



Figure 19: Location of Point 3 (Navigational Gate downstream)

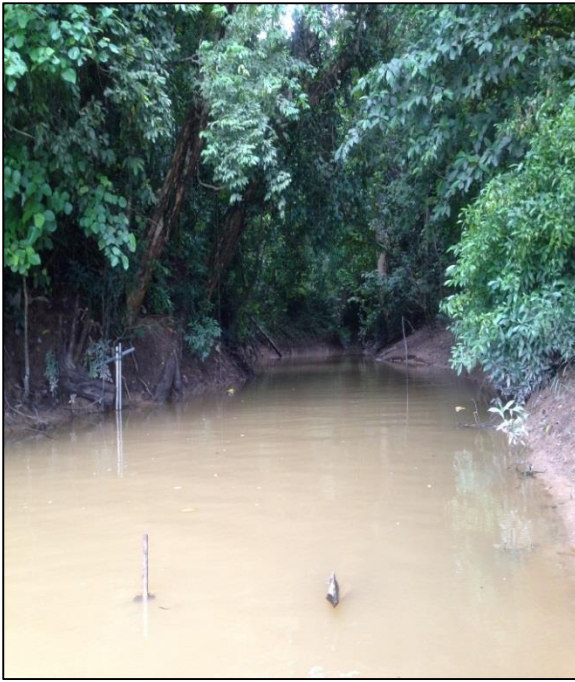


Figure 20: Location of Point 4 (Kuala Sungai Chini)



Figure 21: Location of Point 6 (Sungai Pahang)

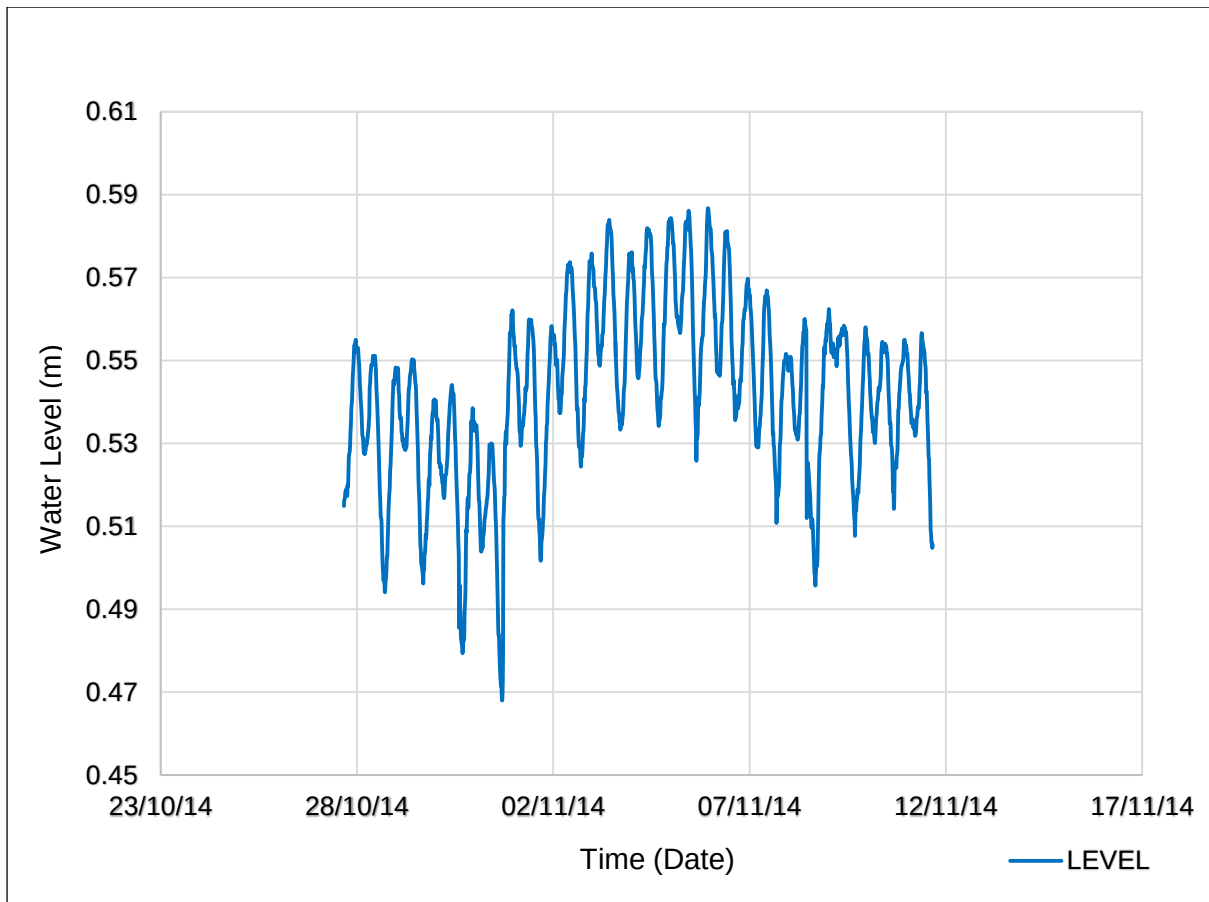


Figure 22: Water level data for Point 1

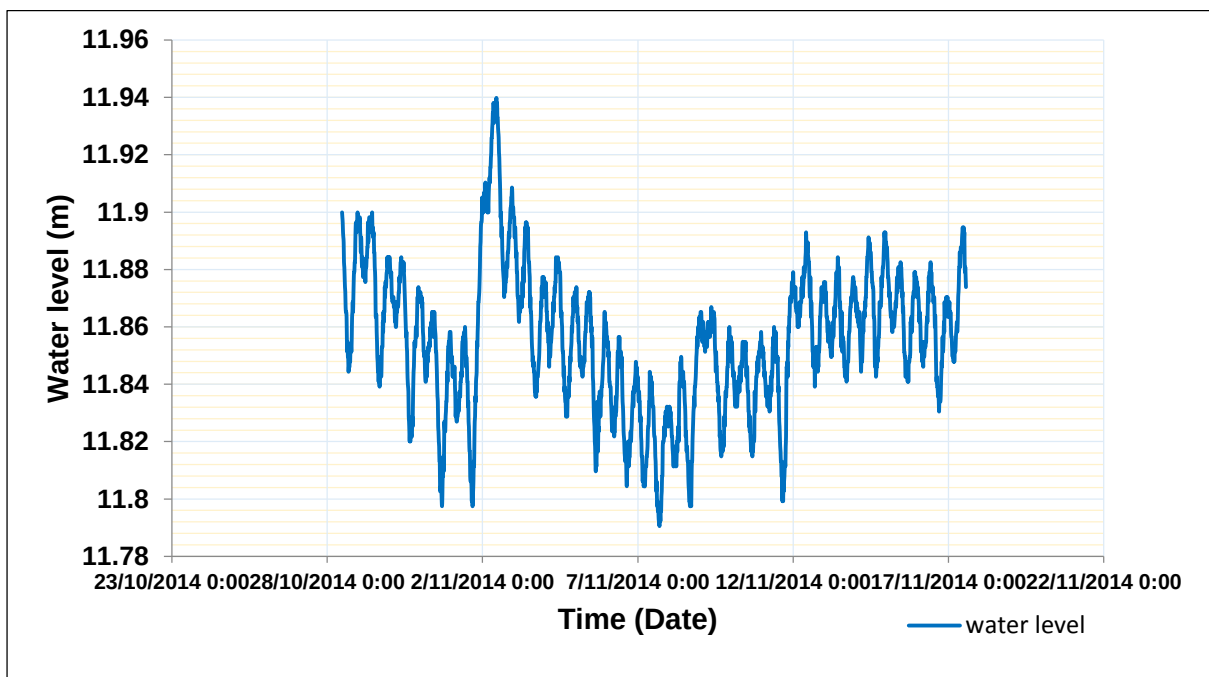


Figure 23: Water level data for Point 2

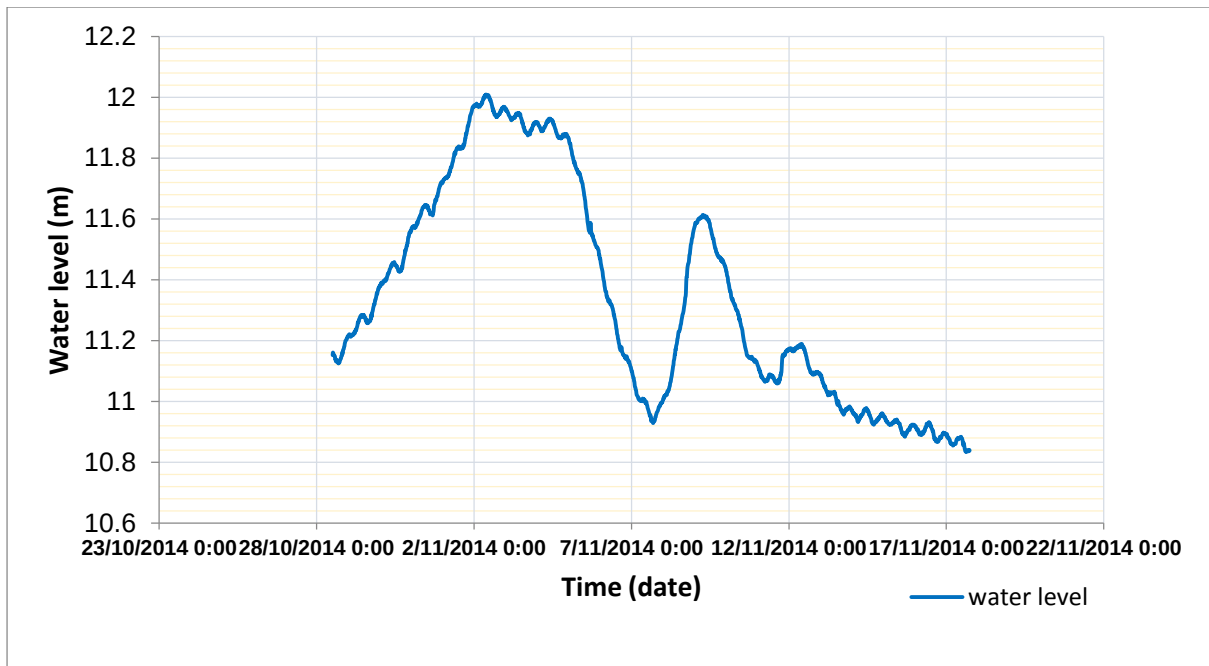


Figure 24: Water level data for Point 3

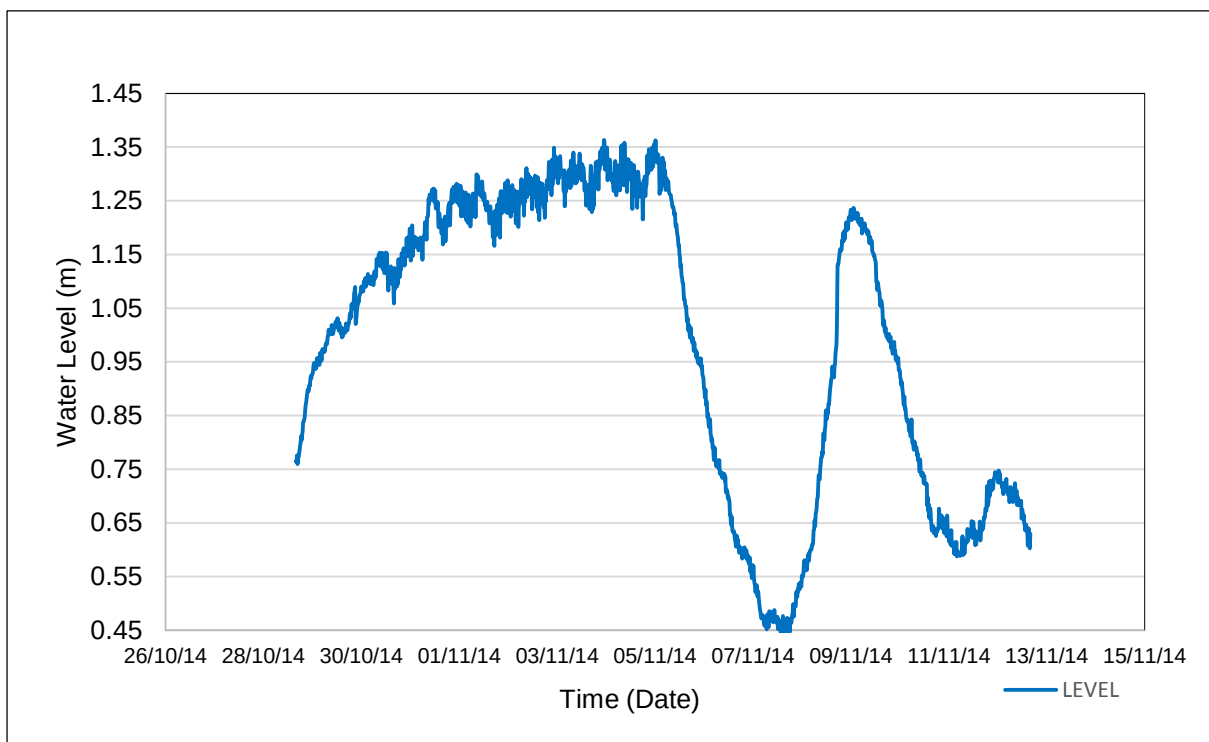


Figure 25: Water level data for Point 4

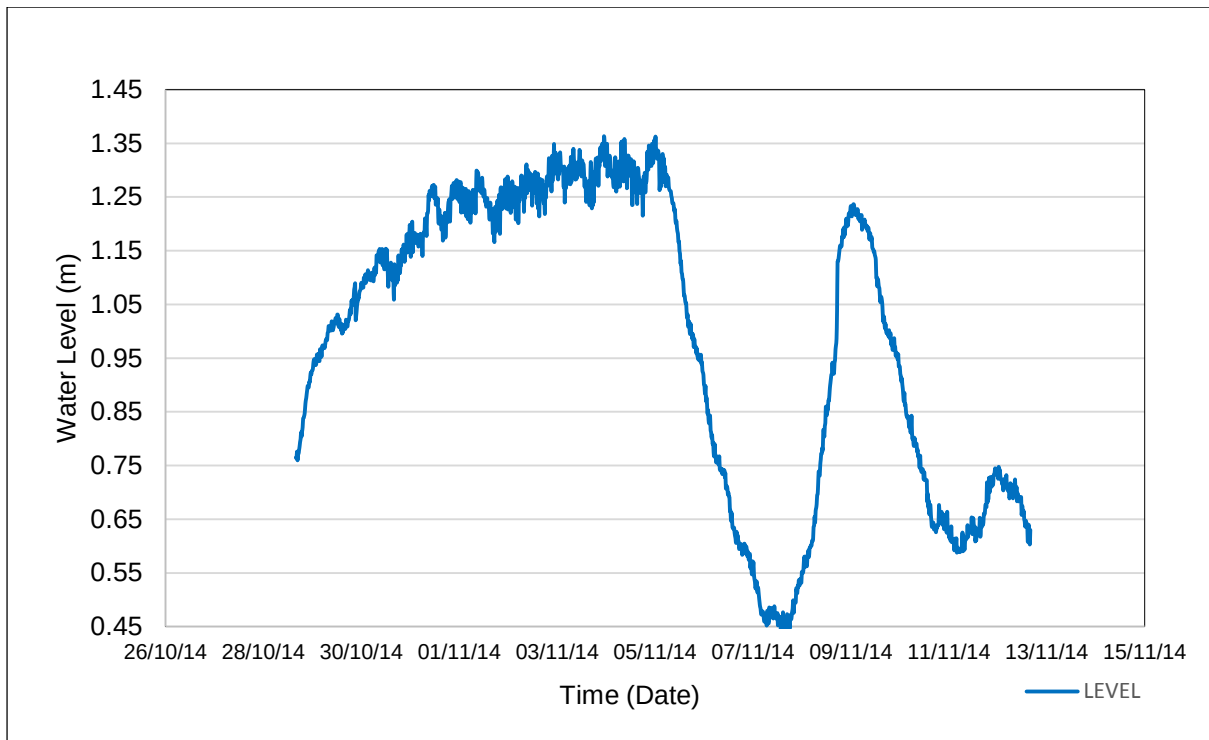


Figure 26: Water level data for Point 5

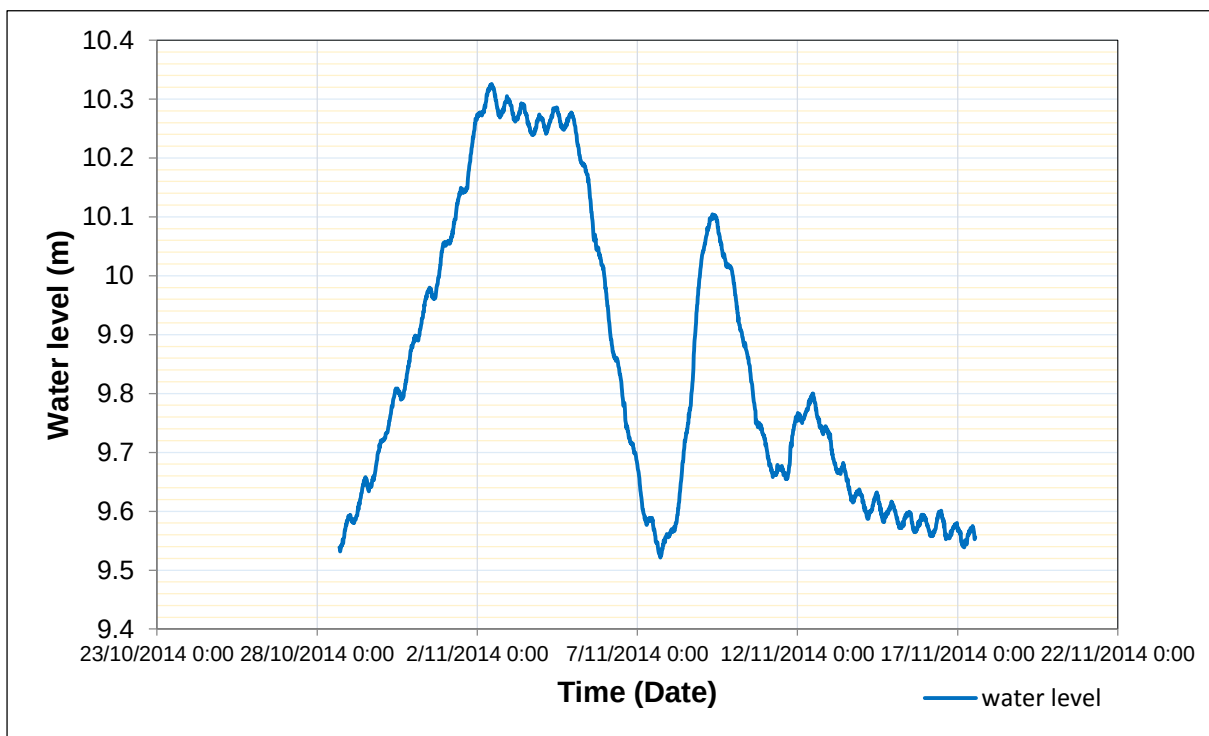


Figure 27: Water level data for Point 6

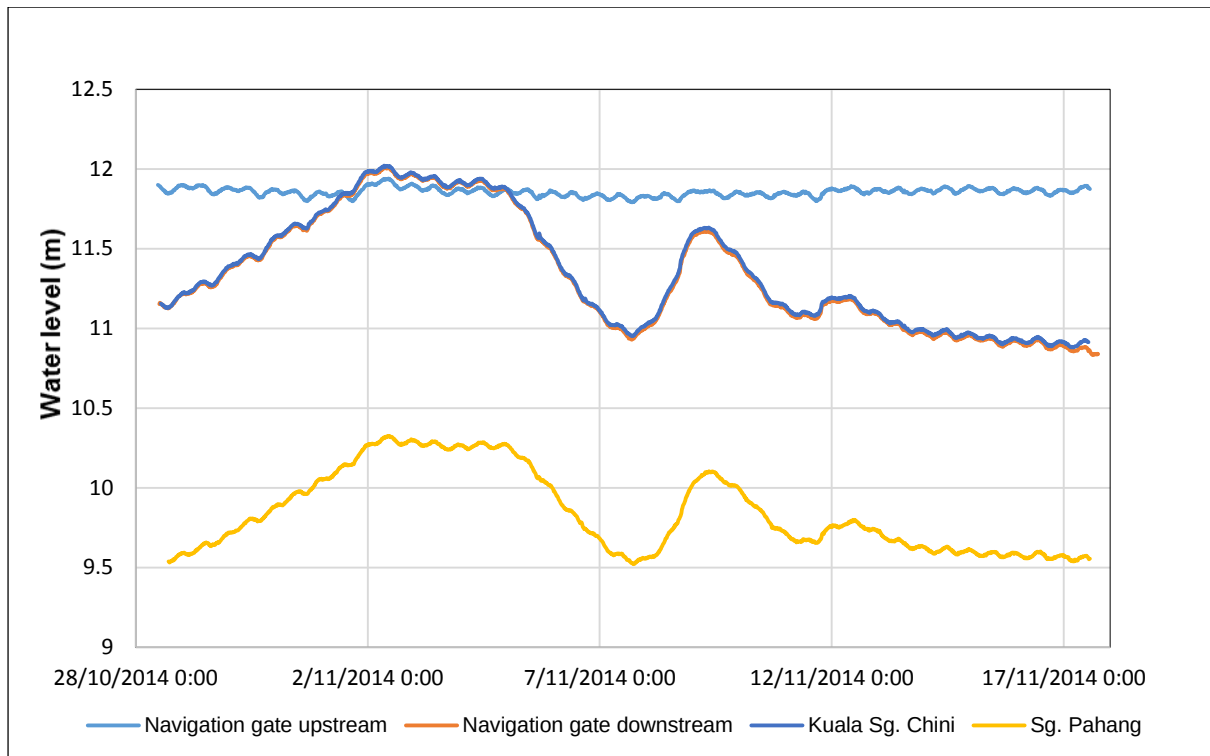


Figure 28: Comparison of water levels at various sampling location

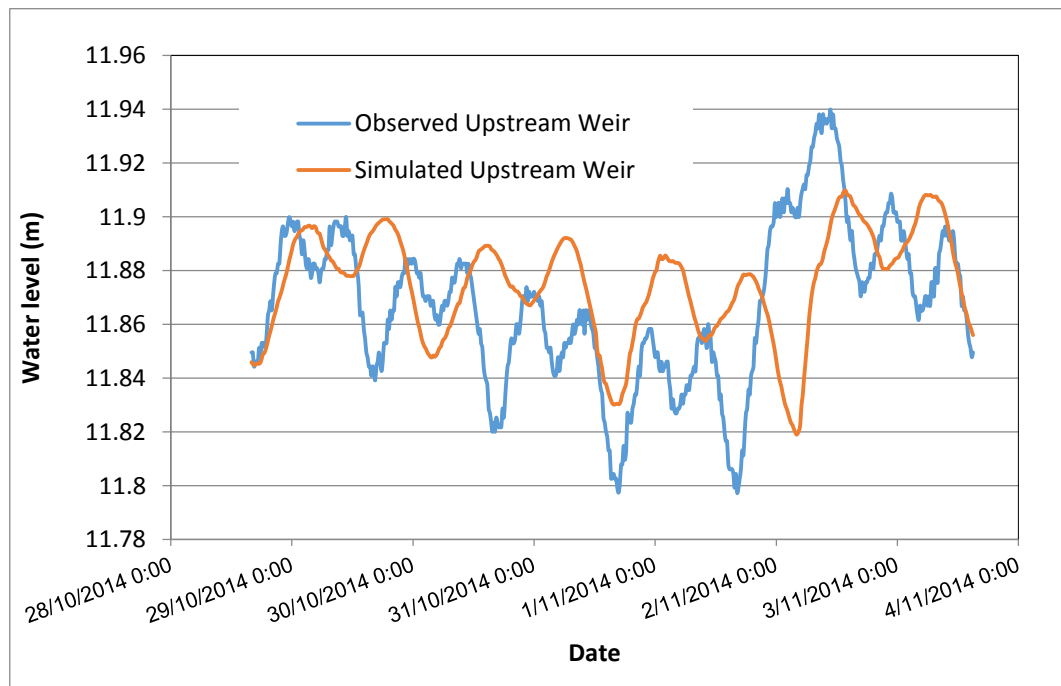


Figure 29: Comparison of observed data and simulated data was done at upstream of weir located at Point 2

6.0 MODEL SIMULATION

Four scenarios were assessed where two scenarios with the current landuse and another two scenarios with the impact of climate change.

6.1 Scenario 1: Current (Landuse) and Baseline (Meteorology)

This scenario simulated the current landuse without the impact of climate change. The simulation results are shown in Table 7 to 8 and Figure 30 to 35.

Table 7: Maximum water level for various ARIs for Scenario 1: Current (Landuse) and Baseline (Meteorology)

ARI	Maximum Water Level (metre)				
Node\Link	10-year	20-year	25-year	50-year	100-year
CH 425 (Weir Upstream)	11.125	11.386	11.497	11.846	12.282
CH 425 (Weir Downstream)	11.028	11.274	11.379	11.704	12.106
Sg Chini CH 4000 (Upstream of Sg Chini)	12.863	13.202	13.318	13.708	14.137

Table 8: Maximum flow for various ARIs for Scenario 1: Current (Landuse) and Baseline (Meteorology)

ARI	Maximum Flow (m3/s)				
Node\Link	10-year	20-year	25-year	50-year	100-year
CH 425 (Weir Upstream)	9.900	12.641	13.926	18.306	24.687
CH 425 (Weir Downstream)	19.799	25.282	27.851	36.612	49.372
Sg Chini CH 4000 (Upstream of Sg Chini)	19.846	25.366	27.942	36.756	49.636

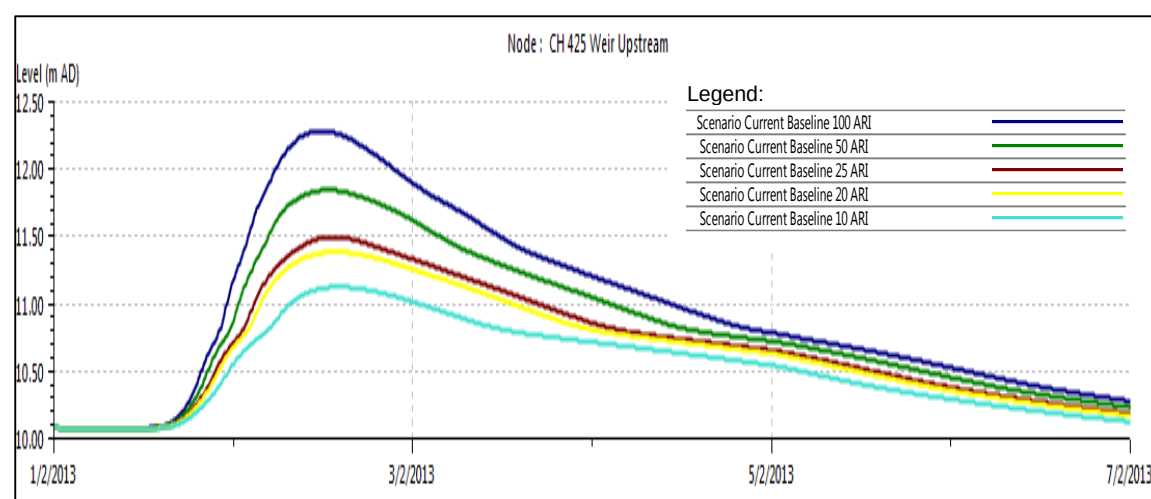


Figure 30: Comparison of Water Level for Various ARIs at CH425 Weir Upstream for Scenario 1: Current (Landuse) and Baseline (Meteorology)

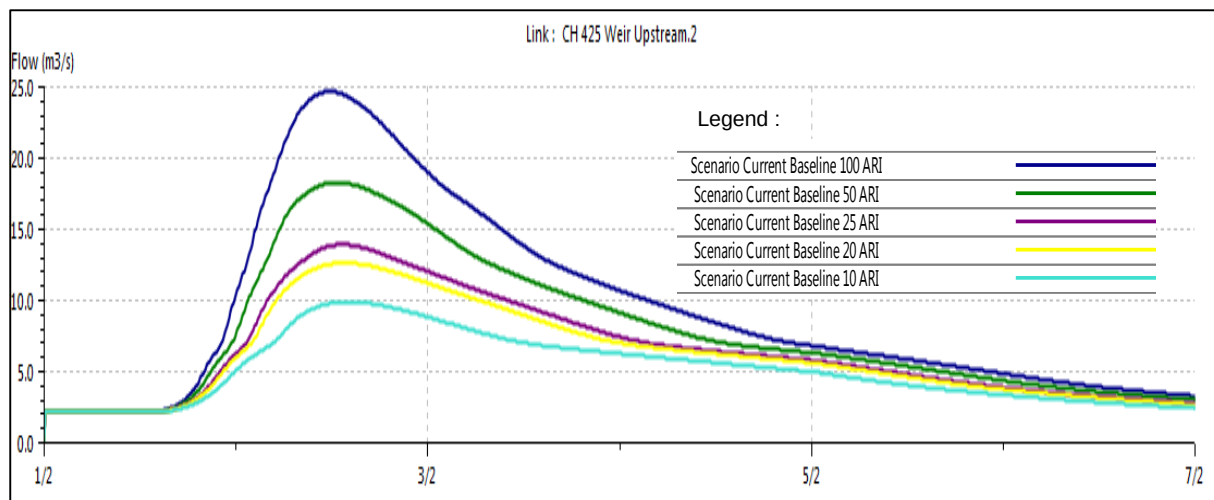


Figure 31: Comparison of Flow for Various ARIs at CH425 Weir Upstream for Scenario 1: Current (Landuse) and Baseline (Meteorology)

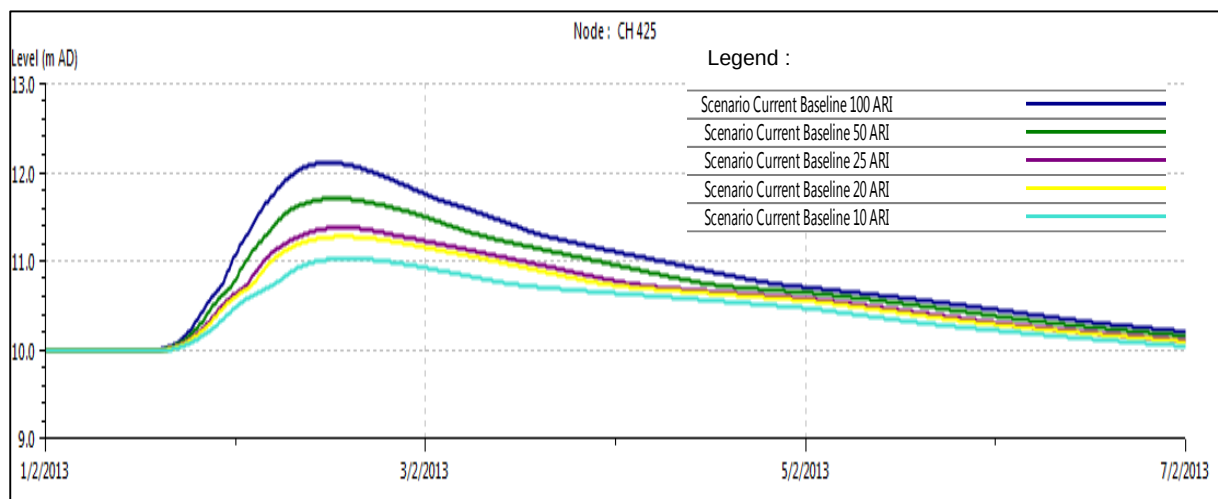


Figure 32: Comparison of Water Level for Various ARIs at CH425 Weir Downstream for Scenario 1: Current (Landuse) and Baseline (Meteorology)

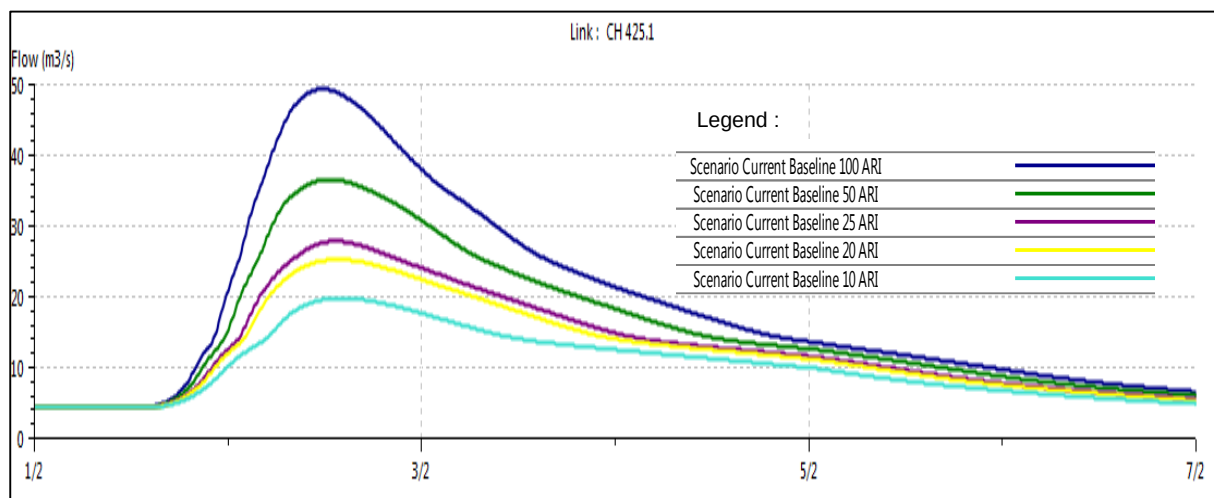


Figure 33: Comparison of Flow for Various ARIs at CH425 Weir Downstream for Scenario 1: Current (Landuse) and Baseline (Meteorology)

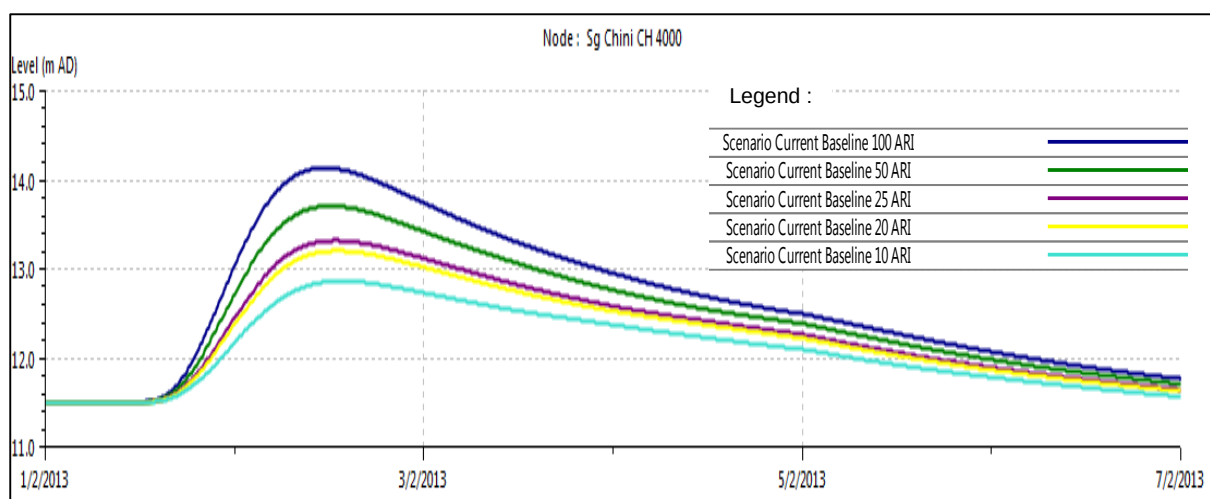


Figure 34: Comparison of Water Level for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 1: Current (Landuse) and Baseline (Meteorology)

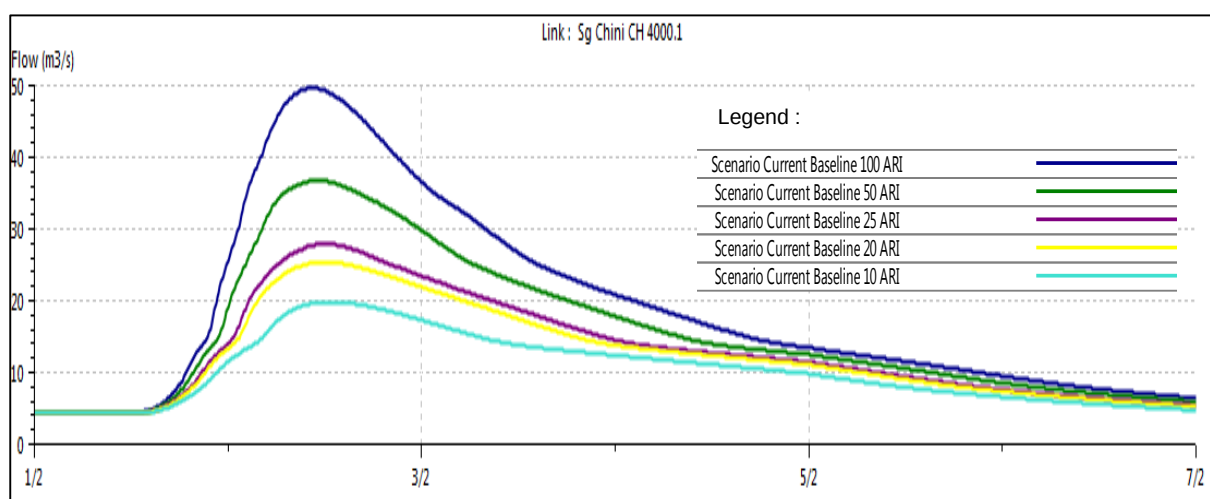


Figure 35: Comparison of Flow for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 1: Current (Landuse) and Baseline (Meteorology)

6.2 Scenario 2: Current (Landuse) and Future (Meteorology)

This scenario simulated the current landuse without the impact of climate change. The simulation results are shown in Table 9 to 10 and Figure 36 to 41.

Table 9: Maximum water level for various ARIs for Scenario 2: Current (Landuse) and Future (Meteorology)

ARI	Maximum Water Level (metre)				
Node/Link	10-year	20-year	25-year	50-year	100-year
CH 425 (Weir Upstream)	12.032	12.574	12.840	13.546	14.128
CH 425 (Weir Downstream)	11.877	12.363	12.597	13.228	13.273
Sg Chini CH 4000 (Upstream of Sg Chini)	13.892	14.464	14.749	15.430	16.040

Table 10: Maximum flow for various ARIs for Scenario 2: Current (Landuse) and Future (Meteorology)

ARI	Maximum Flow (m3/s)				
Node\Link	10-year	20-year	25-year	50-year	100-year
CH 425 (Weir Upstream)	20.903	30.161	35.506	50.030	65.043
CH 425 (Weir Downstream)	41.805	60.321	71.012	100.060	130.086
Sg Chini CH 4000 (Upstream of Sg Chini)	41.969	60.523	71.137	100.251	130.391

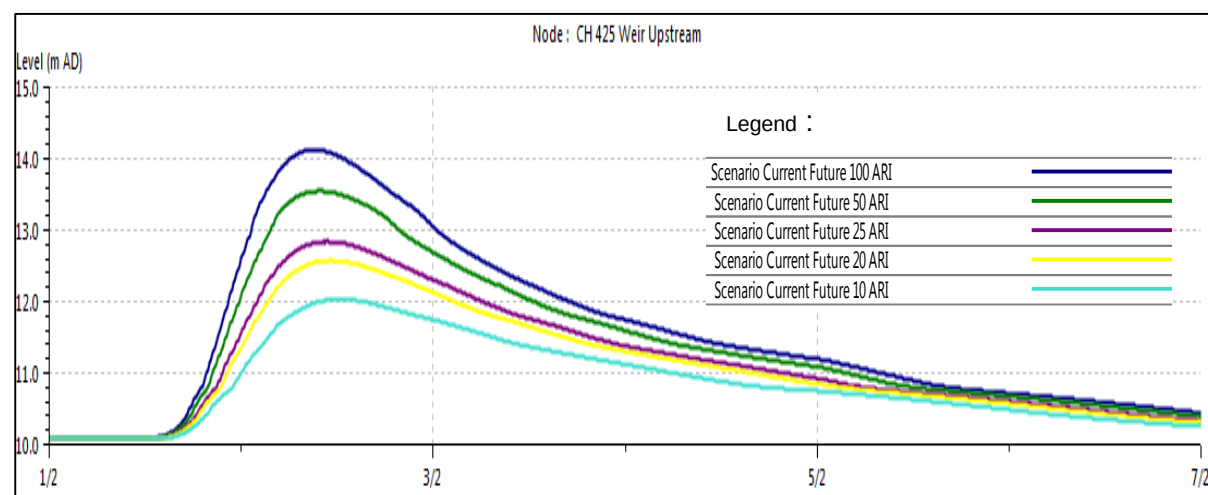


Figure 36: Comparison of Water Level for Various ARIs at CH425 Weir Upstream for Scenario 2: Current (Landuse) and Future (Meteorology)

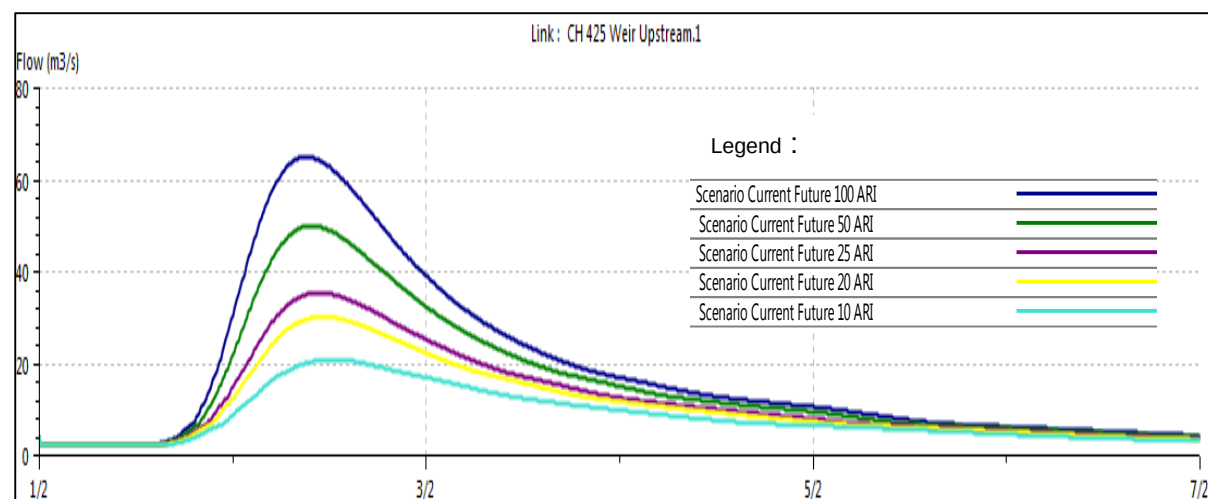


Figure 37: Comparison of Flow for Various ARIs at CH425 Weir Upstream for Scenario 2: Current (Landuse) and Future (Meteorology)

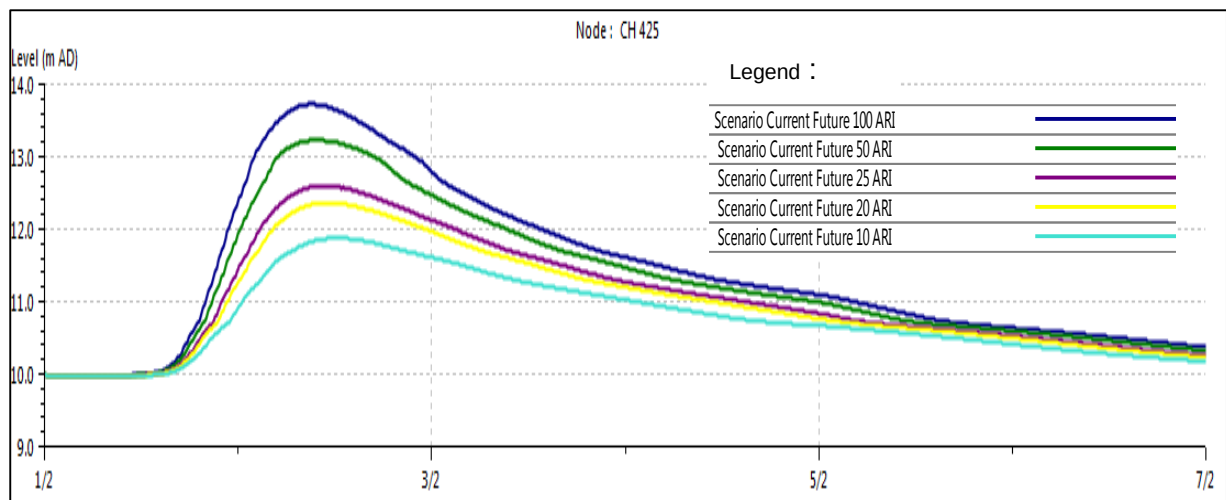


Figure 38: Comparison of Water Level for Various ARIs at CH425 Weir Downstream for Scenario 2: Current (Landuse) and Future (Meteorology)

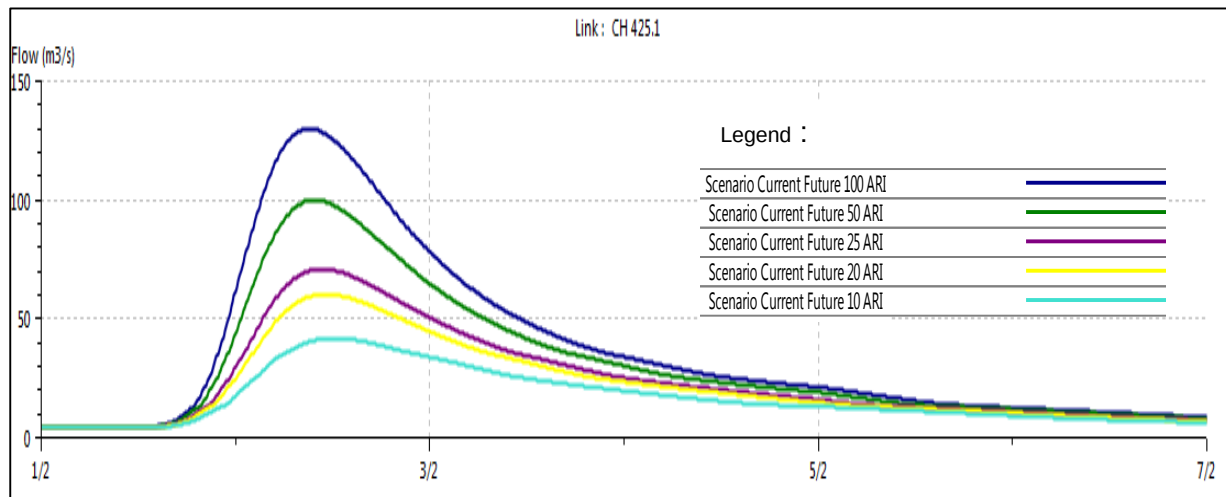


Figure 39: Comparison of Flow for Various ARIs at CH425 Weir Downstream for Scenario 2: Current (Landuse) and Future (Meteorology)

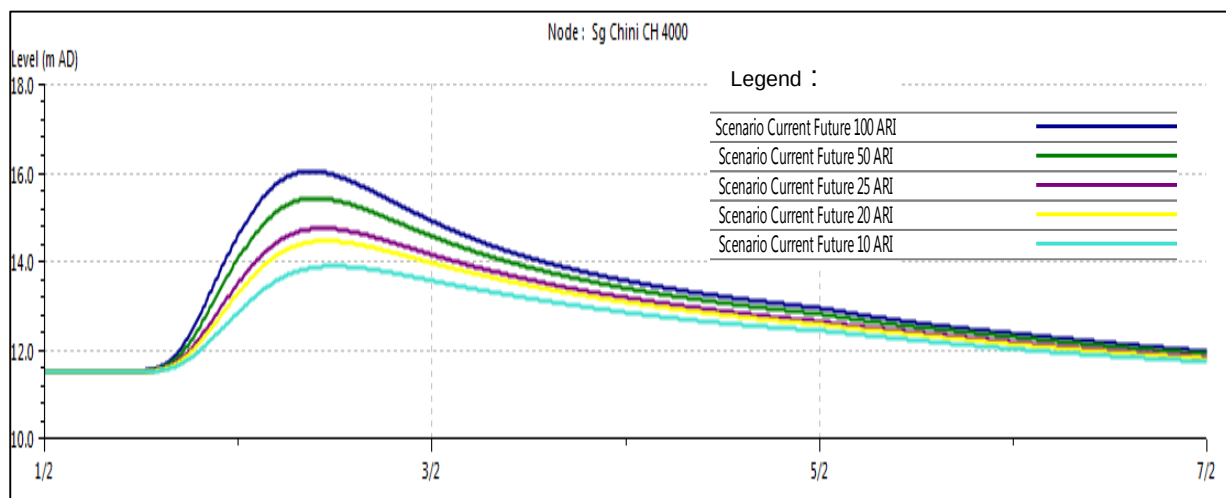


Figure 40: Comparison of Water Level for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 2: Current (Landuse) and Future (Meteorology)

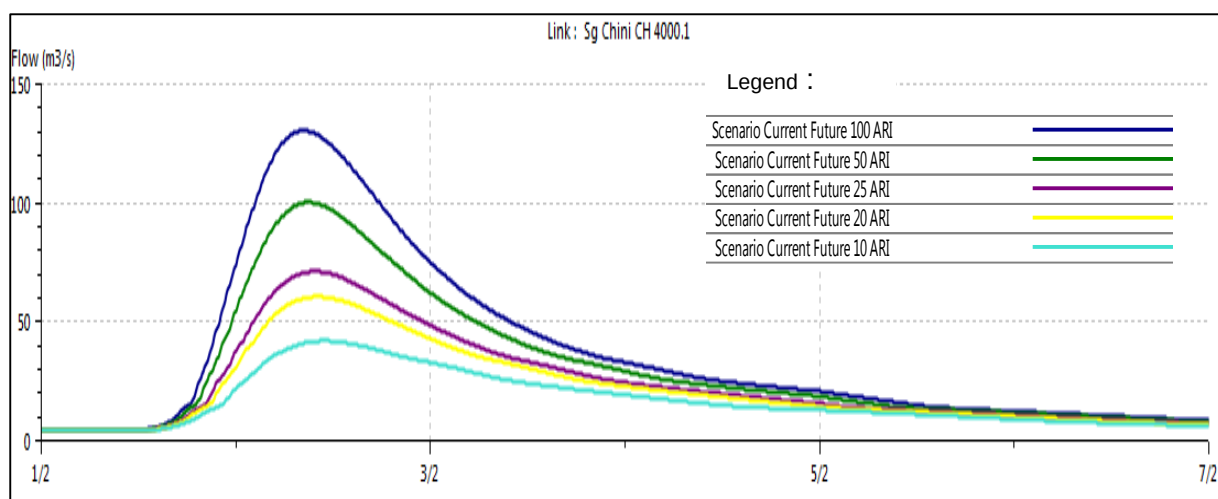


Figure 41: Comparison of Flow for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 2: Current (Landuse) and Future (Meteorology)

6.3 Scenario 3: Future (Landuse) and Baseline (Meteorology)

This scenario simulated the future landuse without the impact of climate change. The simulation results are shown in Table 11 to 12 and Figure 42 to 47.

Table 11: Maximum water level for various ARIs for Scenario 3: Future (Landuse) and Baseline (Meteorology)

ARI	Maximum Water Level (metre)				
Node\Link	10-year	20-year	25-year	50-year	100-year
CH 425 (Weir Upstream)	11.182	11.456	11.578	11.930	12.354
CH 425 (Weir Downstream)	11.081	11.340	11.455	11.782	12.168
Sg Chini CH 4000 (Upstream of Sg Chini)	12.935	13.279	13.395	13.793	14.227

Table 12: Maximum flow for various ARIs for Scenario 3: Future (Landuse) and Baseline (Meteorology)

ARI	Maximum Flow (m3/s)				
Node\Link	10-year	20-year	25-year	50-year	100-year
CH 425 (Weir Upstream)	10.463	13.446	14.896	19.456	26.150
CH 425 (Weir Downstream)	20.925	26.893	29.792	38.911	52.301
Sg Chini CH 4000 (Upstream of Sg Chini)	20.976	26.978	29.888	39.062	52.492

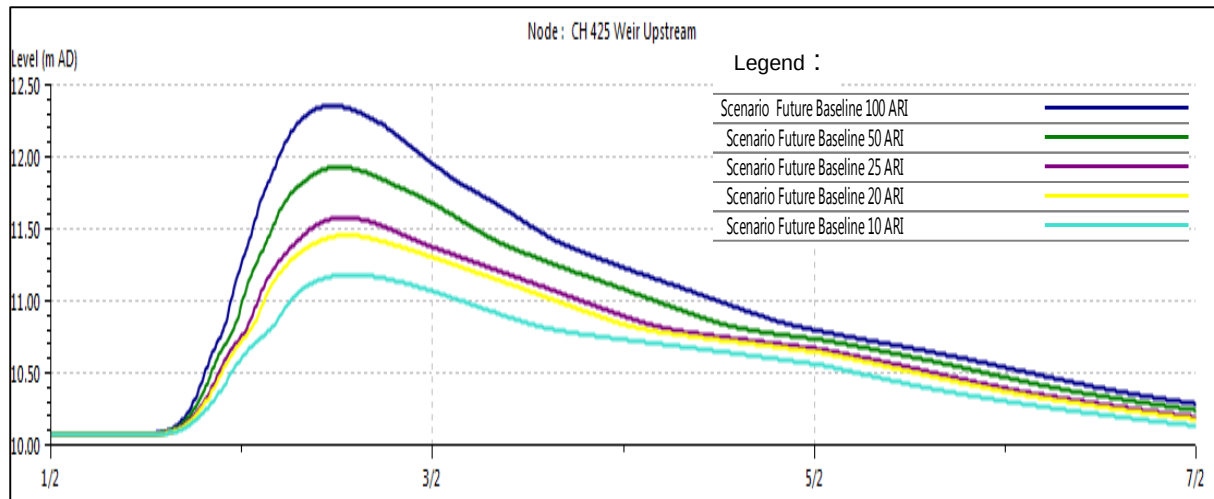


Figure 42: Comparison of Water Level for Various ARIs at CH425 Weir Upstream for Scenario 3: Future (Landuse) and Baseline (Meteorology)

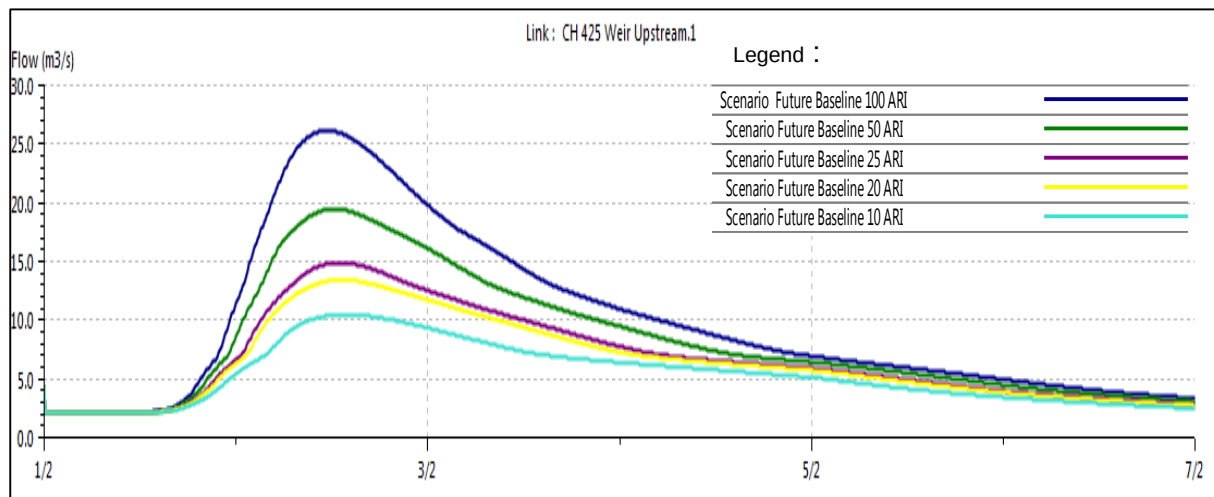


Figure 43: Comparison of Flow for Various ARIs at CH425 Weir Upstream for Scenario 3: Future (Landuse) and Baseline (Meteorology)

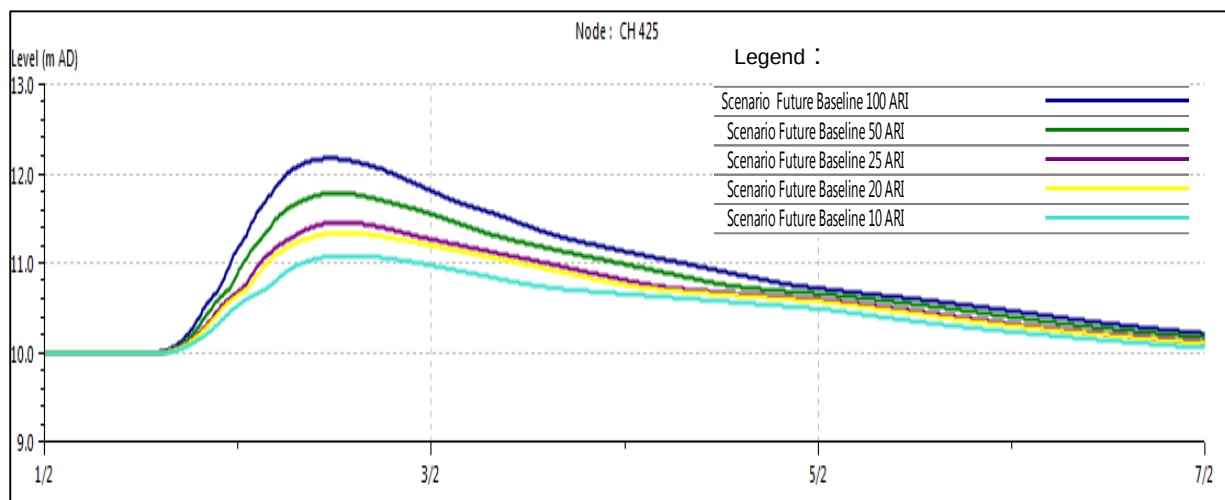


Figure 44: Comparison of Water Level for Various ARIs at CH425 Weir Downstream for Scenario 3: Future (Landuse) and Baseline (Meteorology)

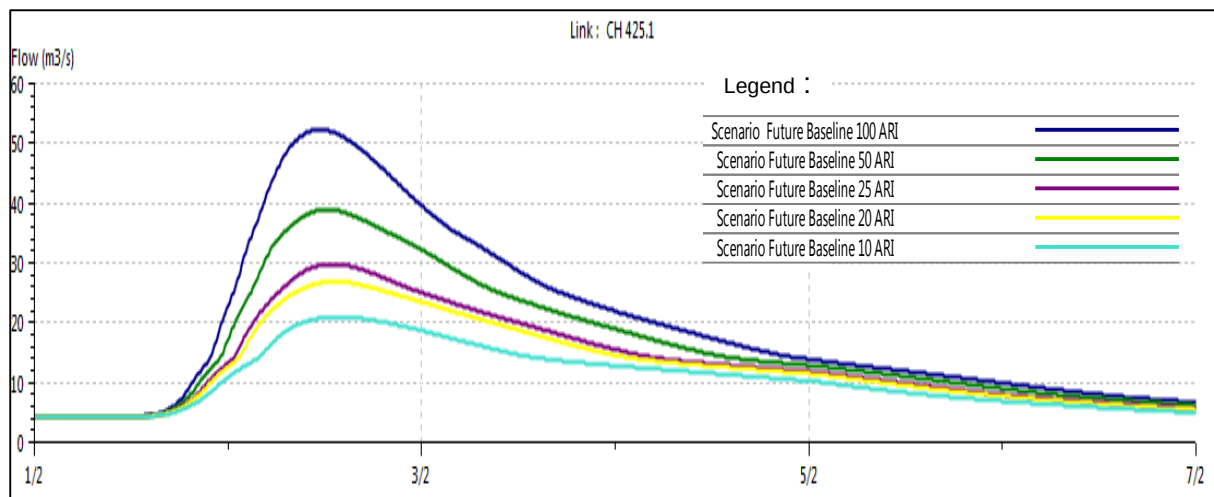


Figure 45: Comparison of Flow for Various ARIs at CH425 Weir Downstream for Scenario 3: Future (Landuse) and Baseline (Meteorology)

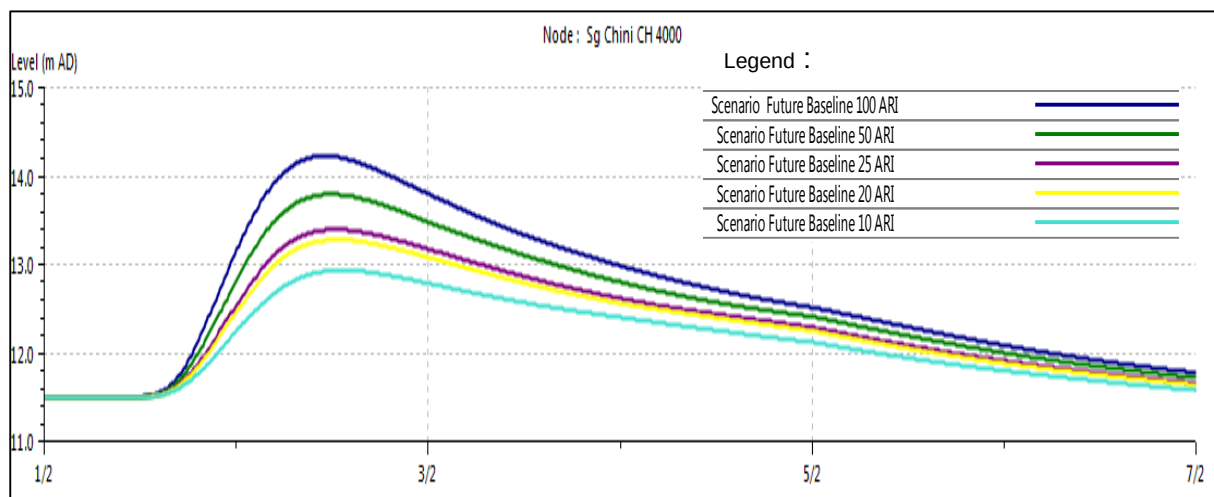


Figure 46: Comparison of Water Level for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 3: Future (Landuse) and Baseline (Meteorology)

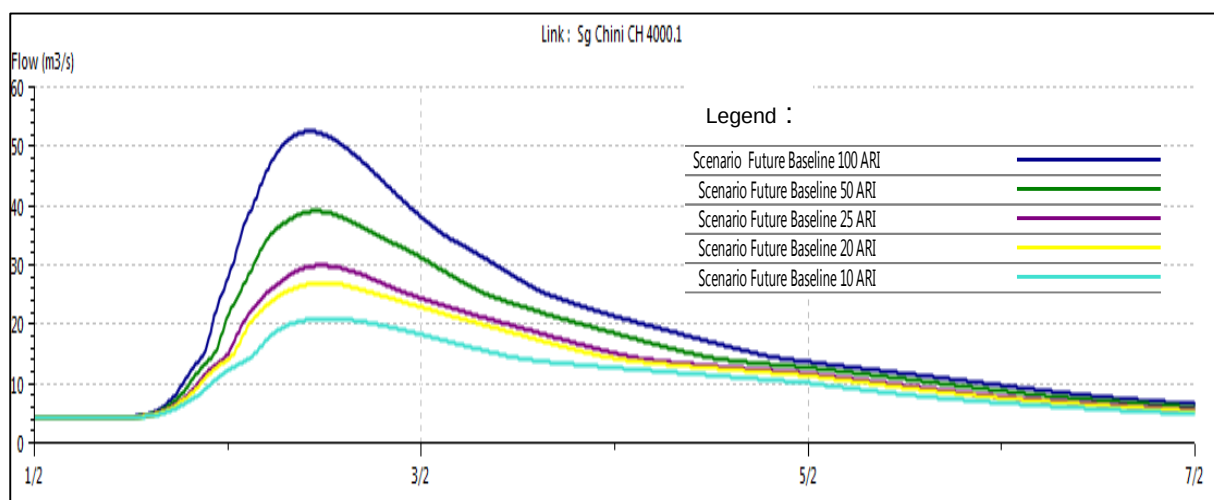


Figure 47: Comparison of Flow for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 3: Future (Landuse) and Baseline (Meteorology)

6.4 Scenario 4: Future (Landuse) and Future (Meteorology)

This scenario simulated the future landuse with the impact of climate change. The simulation results are shown in Table 13-14 and Figure 48 to 53.

Table 13: Maximum water level for various ARIs for Scenario 4: Future (Landuse) and Future (Meteorology)

ARI	Maximum Water Level (metre)				
Node\Link	10-year	20-year	25-year	50-year	100-year
CH 425 (Weir Upstream)	12.123	12.661	12.936	13.645	14.203
CH 425 (Weir Downstream)	11.960	12.440	12.683	13.314	13.787
Sg Chini CH 4000 (Upstream of Sg Chini)	13.978	14.557	14.844	15.530	16.118

Table 14: Maximum flow for various ARIs for Scenario 4: Future (Landuse) and Future (Meteorology)

ARI	Maximum Flow (m3/s)				
Node\Link	10-year	20-year	25-year	50-year	100-year
CH 425 Weir Upstream	22.233	31.828	37.389	52.360	67.081
CH 425 Weir Downstream	44.465	63.657	74.777	104.720	134.161
Sg Chini CH 4000 (Upstream of Sg Chini)	44.634	63.862	74.994	104.971	134.462

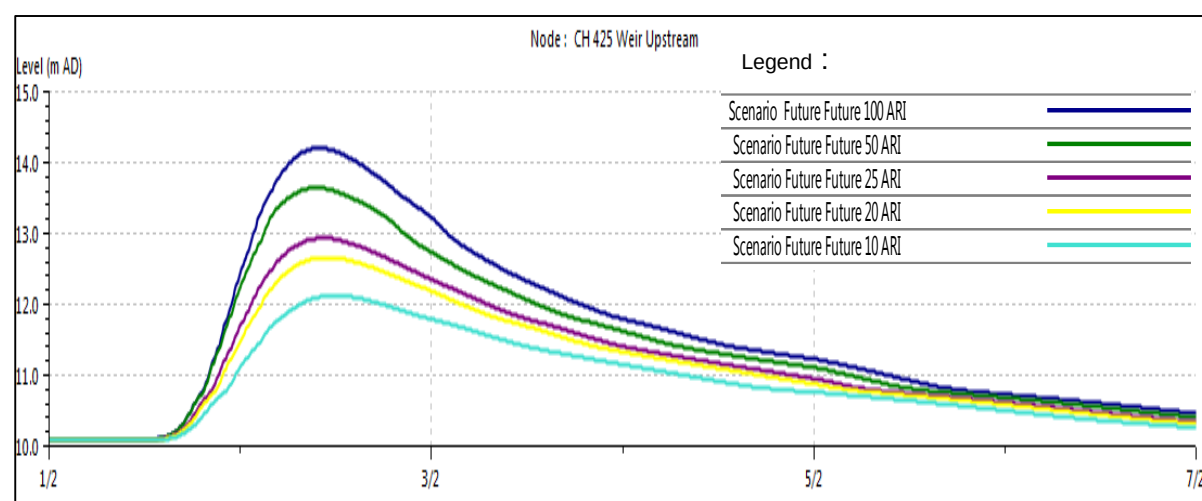


Figure 48: Comparison of Water Level for Various ARIs at CH425 Weir Upstream for Scenario 4: Future (Landuse) and Future (Meteorology)

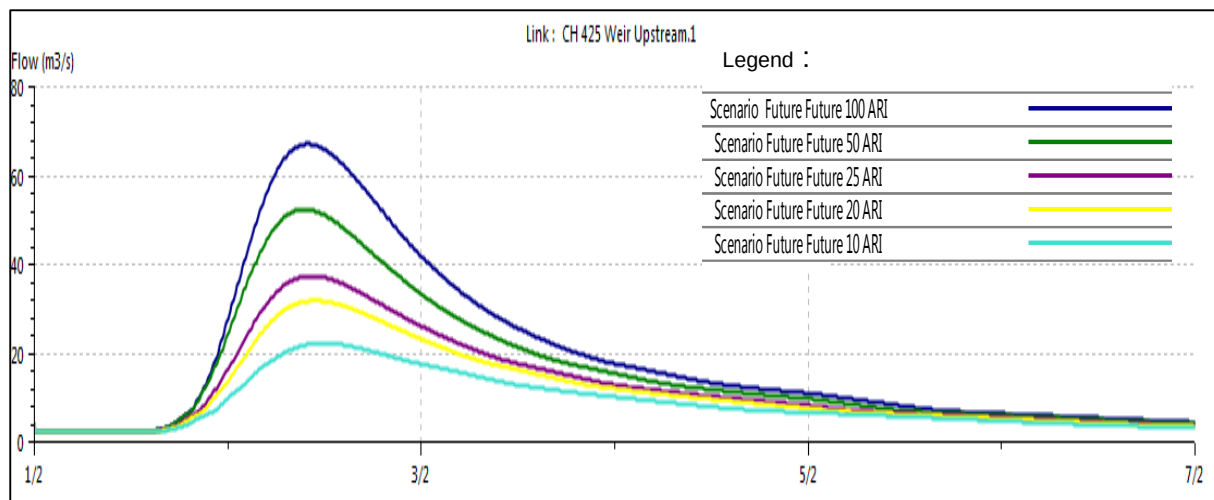


Figure 49: Comparison of Flow for Various ARIs at CH425 Weir Upstream for Scenario 4: Future (Landuse) and Future (Meteorology)

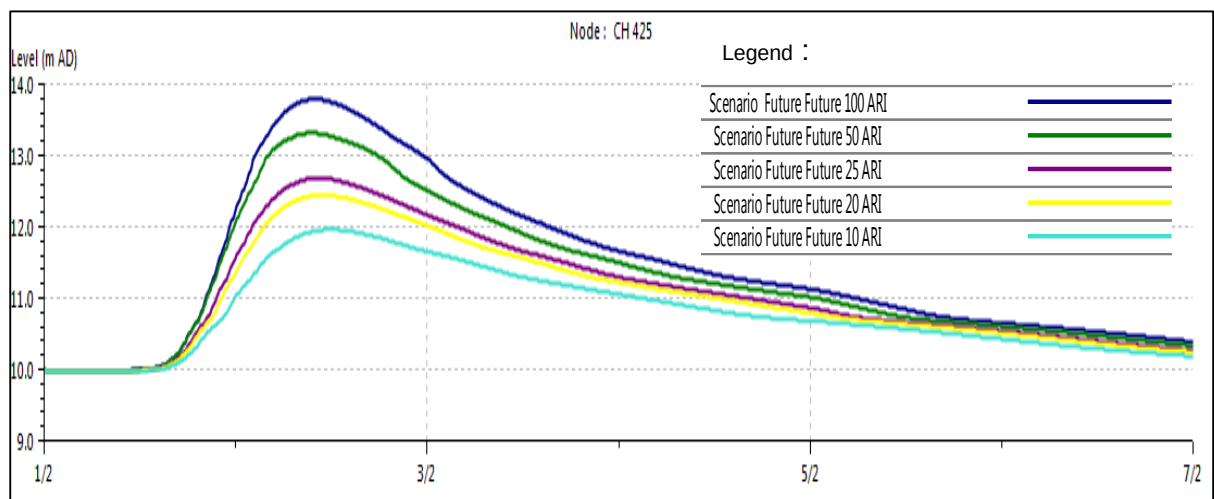


Figure 50: Comparison of Water Level for Various ARIs at CH425 Weir Downstream for Scenario 4: Future (Landuse) and Future (Meteorology)

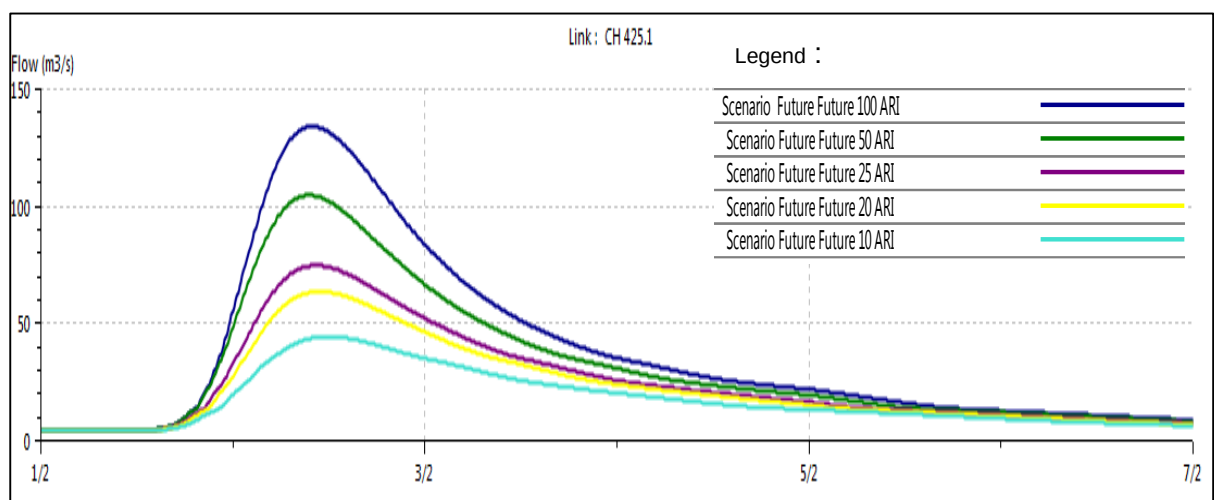


Figure 51: Comparison of Flow for Various ARIs at CH425 Weir Downstream for Scenario 4: Future (Landuse) and Future (Meteorology)

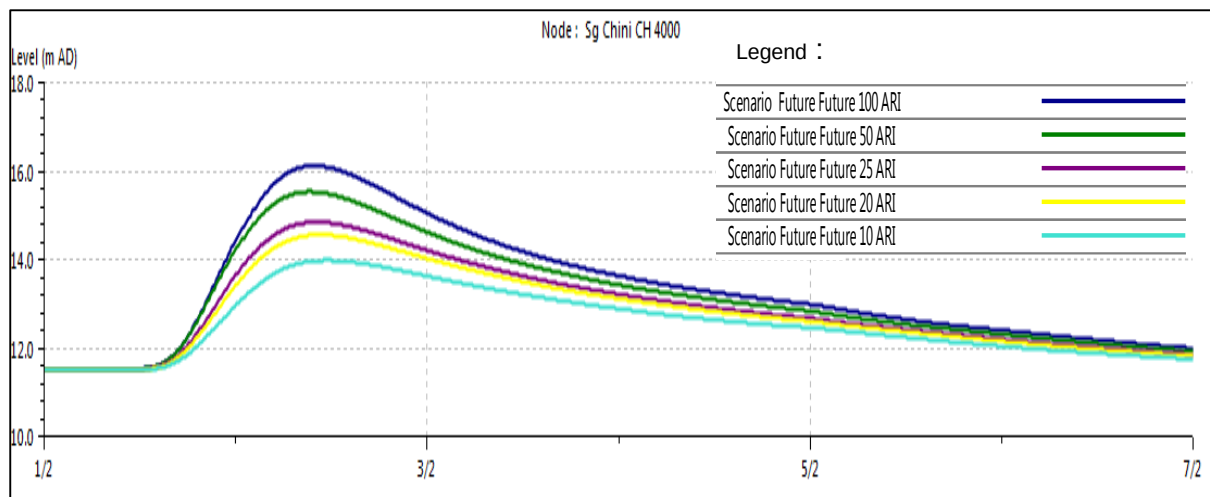


Figure 52: Comparison of Water Level for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 4: Future (Landuse) and Future (Meteorology)

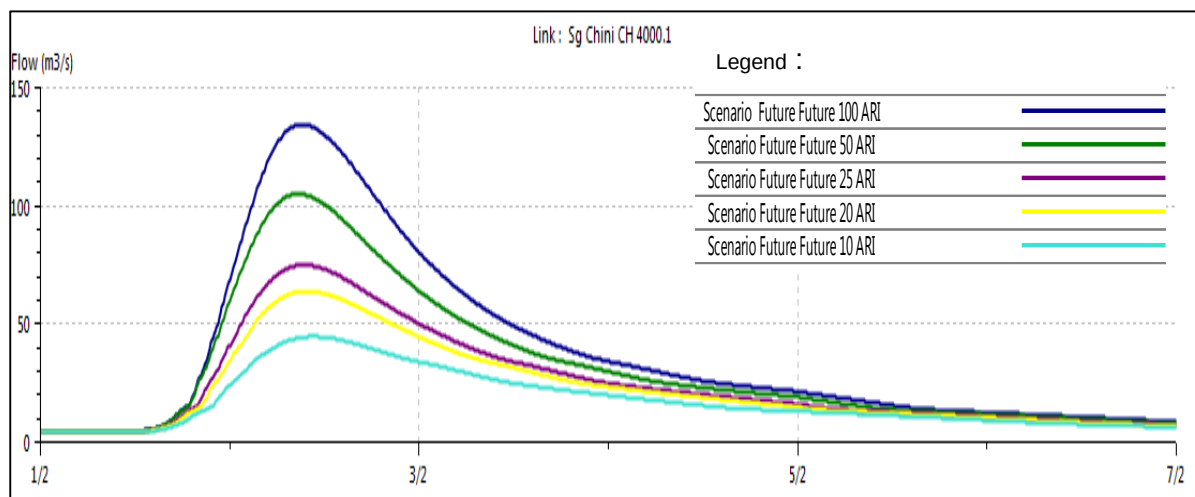


Figure 53: Comparison of Flow for Various ARIs at Sg Chini CH 4000 (Upstream of Sg Chini) for Scenario 4: Future (Landuse) and Future (Meteorology)

7.0 RESULTS AND DISCUSSION

7.1 Impact of Landuse Change

An assessment was done to examine the impact of landuse (from existing to future land use) for various ARIs. The assessment is carried out by comparing the Scenario 1: Current (Landuse) and Baseline (Meteorology) and Scenario 3: Future (Landuse) and Baseline (Meteorology). Table 15 and Figures 54 to 59 show the assessment on the impact of landuse change for 10-year ARI, Table 16 and Figures 60 to 65 show the assessment on the impact of landuse change for 20-year ARI, Table 17 and Figures 66 to 71 show the assessment on the impact of landuse change for 25-year ARI, Table 18 and Figures 72 to 77 show the assessment on the impact of landuse change for 50-year ARI and Table 19 and Figures 78 to 83 show the assessment on the impact of landuse change for 100-year ARI.

Generally, the results show a minimal increment in both water level and flow for various ARIs under the impact of landuse change since 2010 to 2015 with minimal increase of 0.053 m (0.481%) to 0.09 m (0.637%) for water level and minimal increase of 0.563 m³/s (5.69%) to 2.929 m³/s (5.933%) . At particular location at CH 425 (Weir Upstream), the results depicted higher water level from 0.057 m (0.512%) to 0.084m (0.709%) and higher flow from 0.563 m³/s (5.690%) to 1.460 m³/s (5.926%). At CH 425 (Weir Downstream), the results show an increment from 0.053 m (0.481%) to 0.078 m (0.666%) in water level, while increment ranging from 1.126 m³/s (5.687%) to 2.929 m³/s (5.933%) for flow. The results also demonstrate an increment ranging from 0.072 meter (0.560%) to 0.090 meter (0.637%) in water level, while increment ranging from 1.130 m³/s (5.694%) to 2.856 m³/s (5.754%) at Sg Chini CH 4000 (Upstream of Sg Chini).

Table 15: Assessment on the impact of landuse change for 10-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current Landuse	Future Landuse	Differences (m/%)	Current Landuse	Future Landuse	Differences (m ³ /s/%)
	10-year	10-year		10-year	10-year	
CH 425 (Weir Upstream)	11.125	11.182	+0.057 (0.512%)	9.900	10.463	+0.563 (5.687%)
CH 425 (Weir Downstream)	11.028	11.081	+0.053 (0.481%)	19.799	20.925	+1.126 (5.687%)
Sg Chini CH 4000 (Upstream of Sg Chini)	12.863	12.935	+0.072 (0.560%)	19.846	20.976	+1.13 (5.694%)

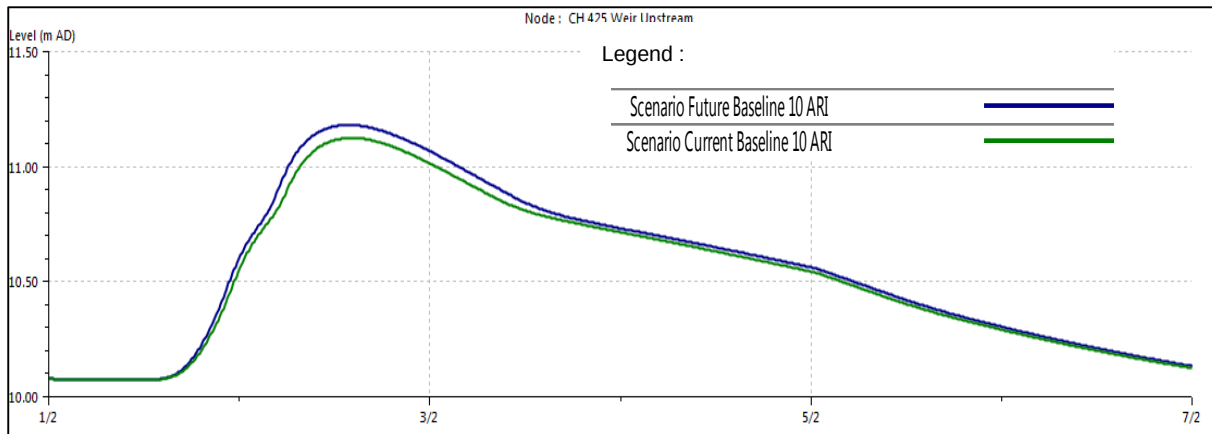


Figure 54: Comparison of water level on the impact of landuse change for 10-year ARI at CH425 Weir Upstream

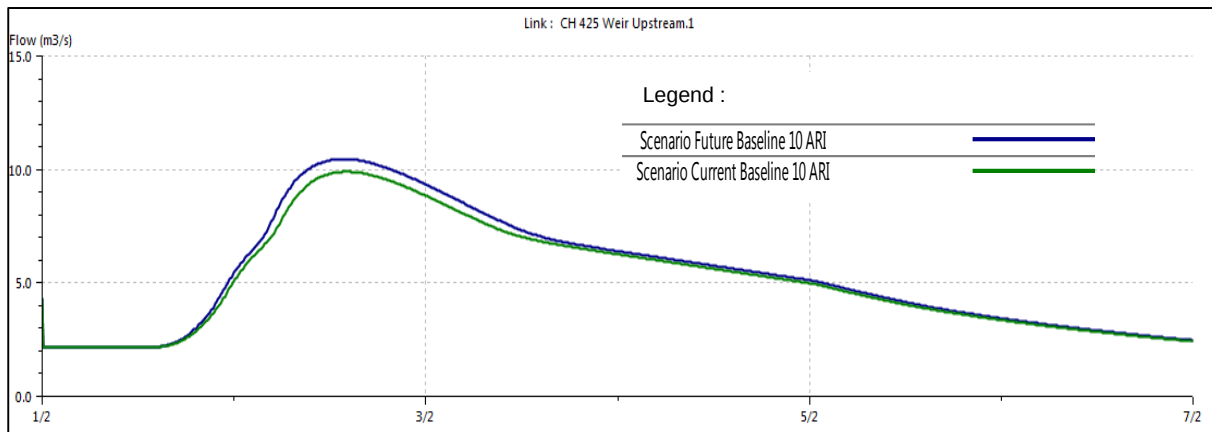


Figure 55: Comparison of flow on the impact of landuse change for 10-year ARI at CH425 Weir Upstream

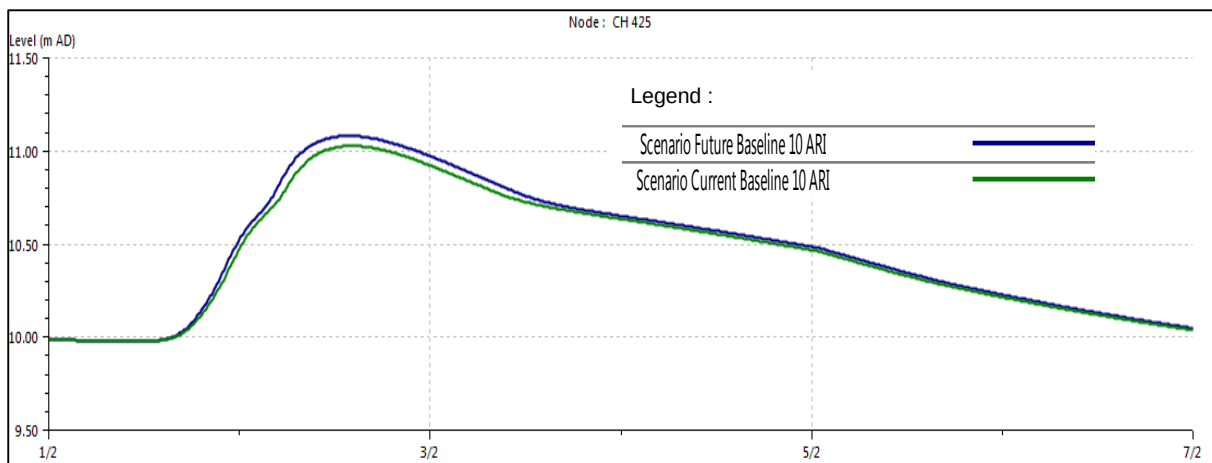


Figure 56: Comparison of water level on the impact of landuse change for 10-year ARI at CH425 Weir Downstream

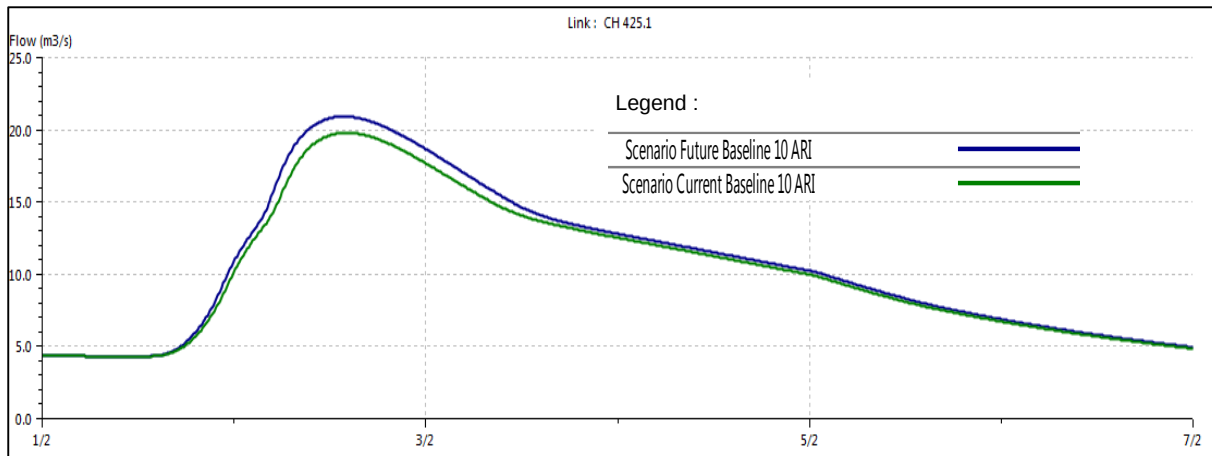


Figure 57: Comparison of flow on the impact of landuse change for 10-year ARI at CH425
Weir Downstream

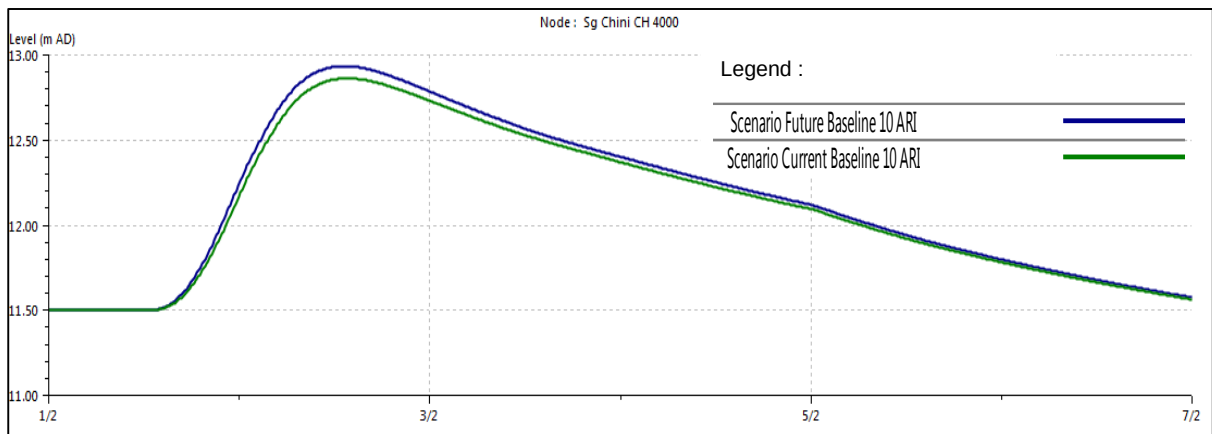


Figure 58: Comparison of water level on the impact of landuse change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

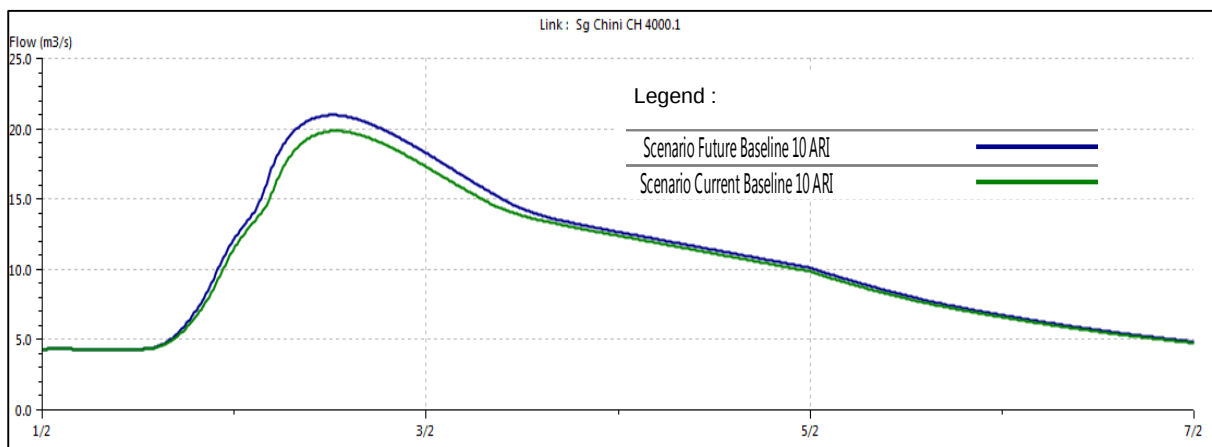


Figure 59: Comparison of flow on the impact of landuse change for 10-year ARI at Sg Chini
CH 4000 (Upstream of Sg Chini)

Table 16: Assessment on the impact of landuse change for 20-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current Landuse	Future Landuse	Differences (m/%)	Current Landuse	Future Landuse	Differences (m ³ /s/%)
	20-year	20-year		20-year	20-year	
CH 425 (Weir Upstream)	11.386	11.456	+0.070 (0.615%)	12.641	13.446	+0.805 (6.368%)
CH 425 (Weir Downstream)	11.274	11.340	+0.066 (0.585%)	25.282	26.893	+1.611 (6.372%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.202	13.279	+0.077 (0.583%)	25.366	26.978	+1.612 (6.355%)

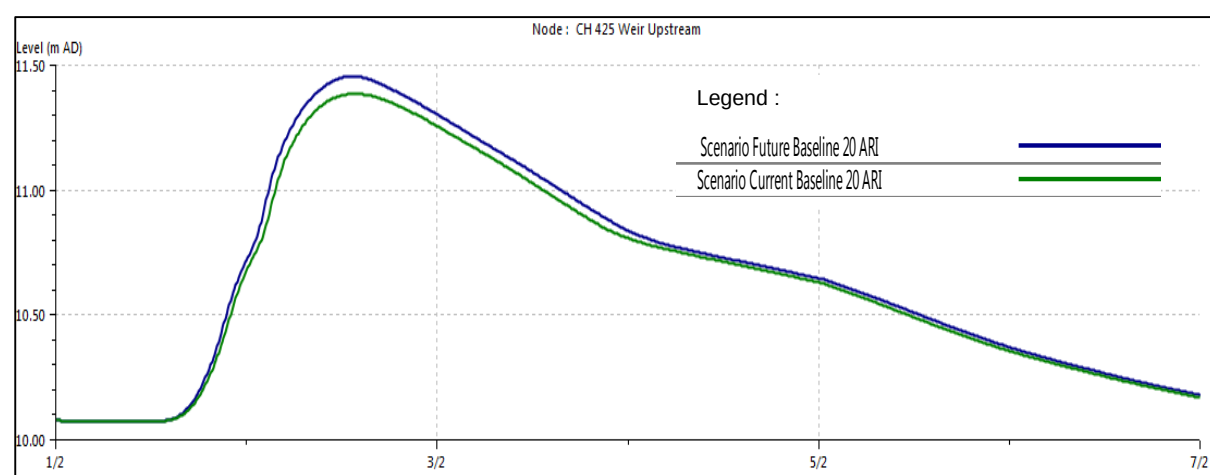


Figure 60: Comparison of water level on the impact of landuse change for 20-year ARI at CH425 Weir Upstream

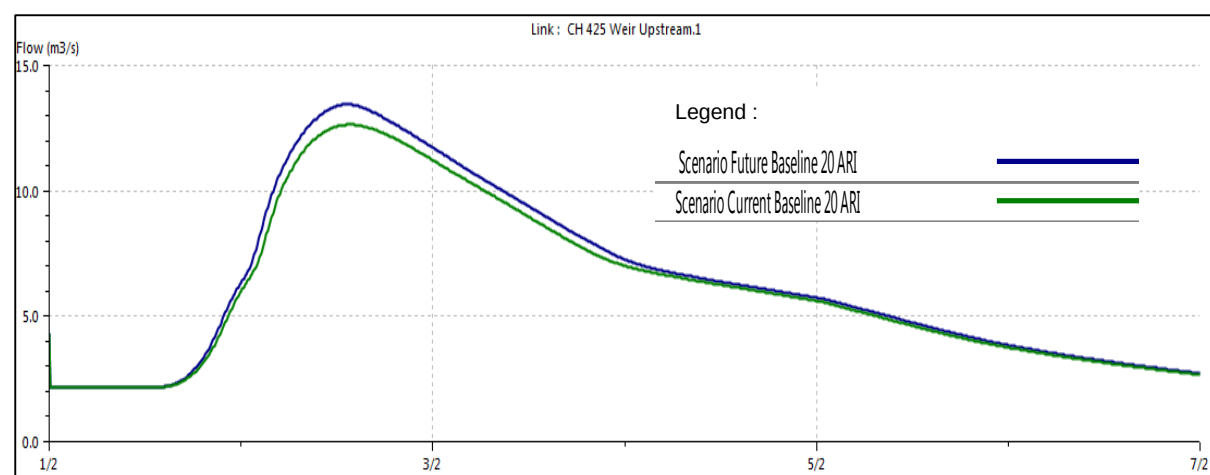


Figure 61: Comparison of flow on the impact of landuse change for 20-year ARI at CH425 Weir Upstream

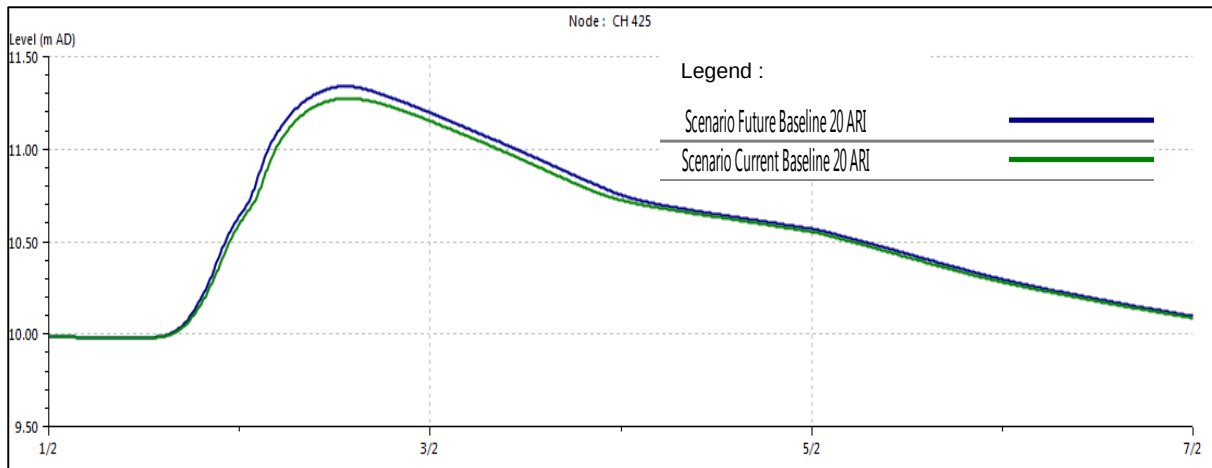


Figure 62: Comparison of water level on the impact of landuse change for 20-year ARI at CH425 Weir Downstream

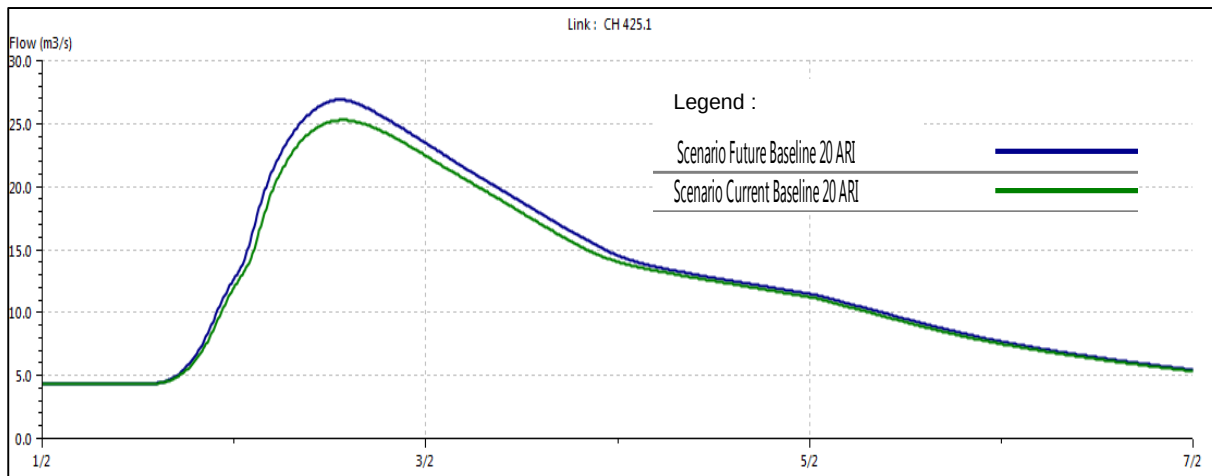


Figure 63: Comparison of flow on the impact of landuse change for 20-year ARI at CH425 Weir Downstream

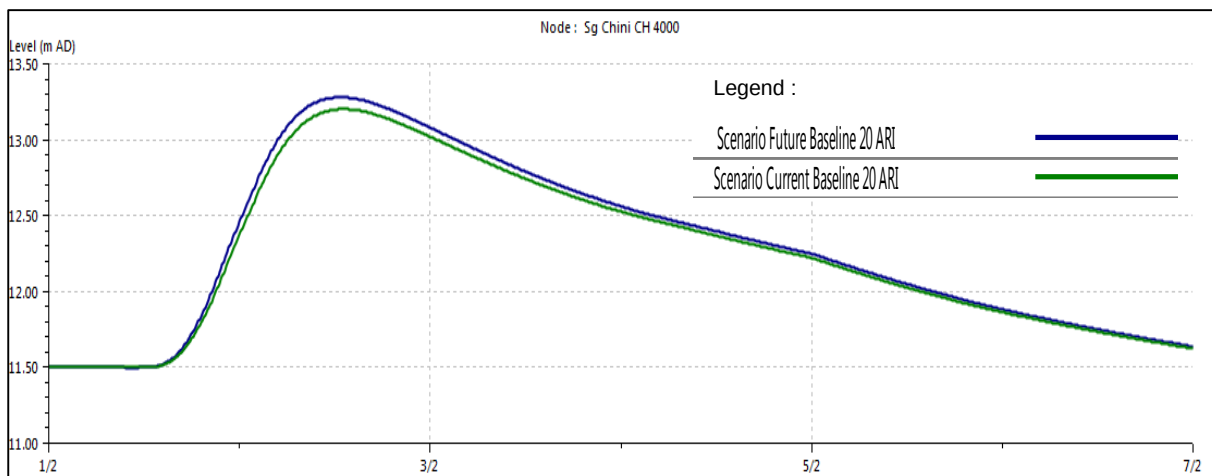


Figure 64: Comparison of water level on the impact of landuse change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

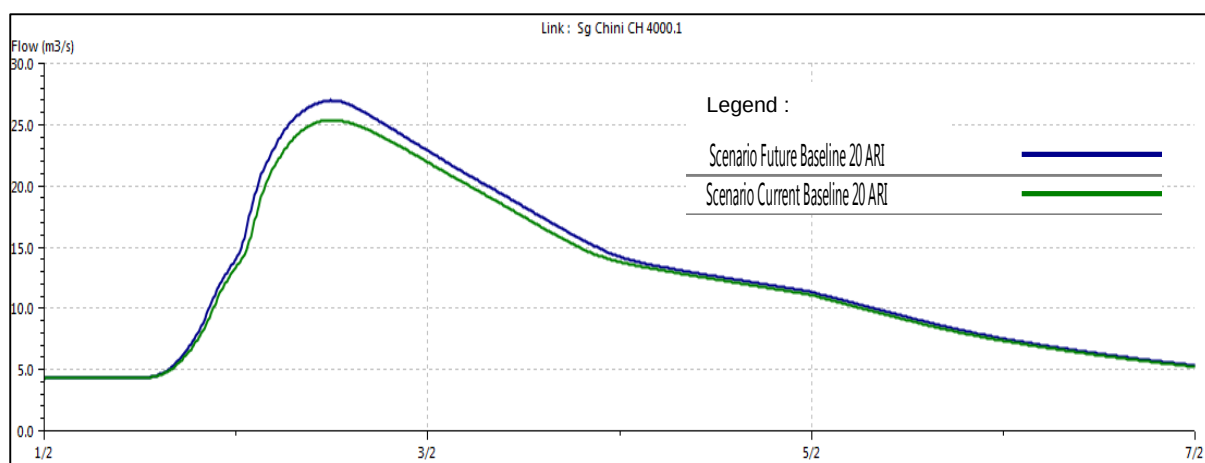


Figure 65: Comparison of flow on the impact of landuse change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 17: Assessment on the impact of landuse change for 25-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m³/s		
	Current Landuse	Future Landuse	Differences (m/%)	Current Landuse	Future Landuse	Differences (m³/s/%)
	25-year	25-year		25-year	25-year	
CH 425 (Weir Upstream)	11.497	11.578	+0.081 (0.705%)	13.926	14.896	+0.97 (6.965%)
CH 425 (Weir Downstream)	11.379	11.455	+0.076 (0.668%)	27.851	29.792	+1.941 (6.969%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.318	13.395	+0.077 (0.578%)	27.942	29.888	+1.946 (6.964%)

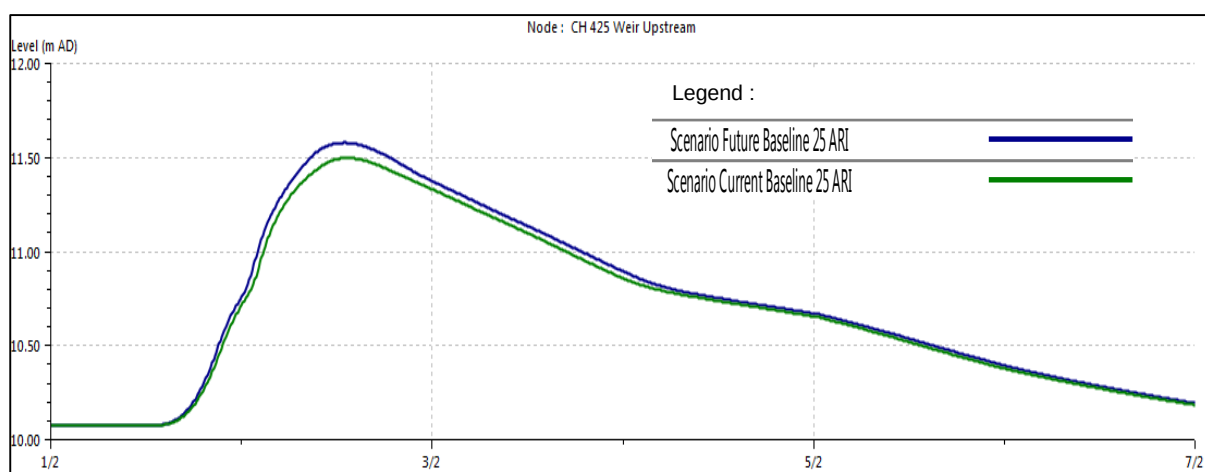


Figure 66: Comparison of water level on the impact of landuse change for 25-year ARI at CH425 Weir Upstream

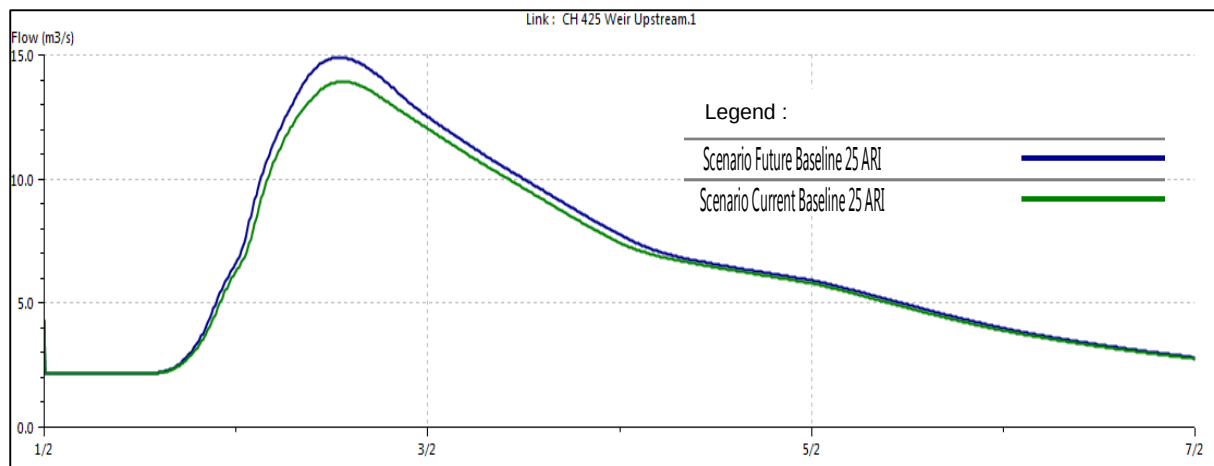


Figure 67: Comparison of flow on the impact of landuse change for 25-year ARI at CH425 Weir Upstream

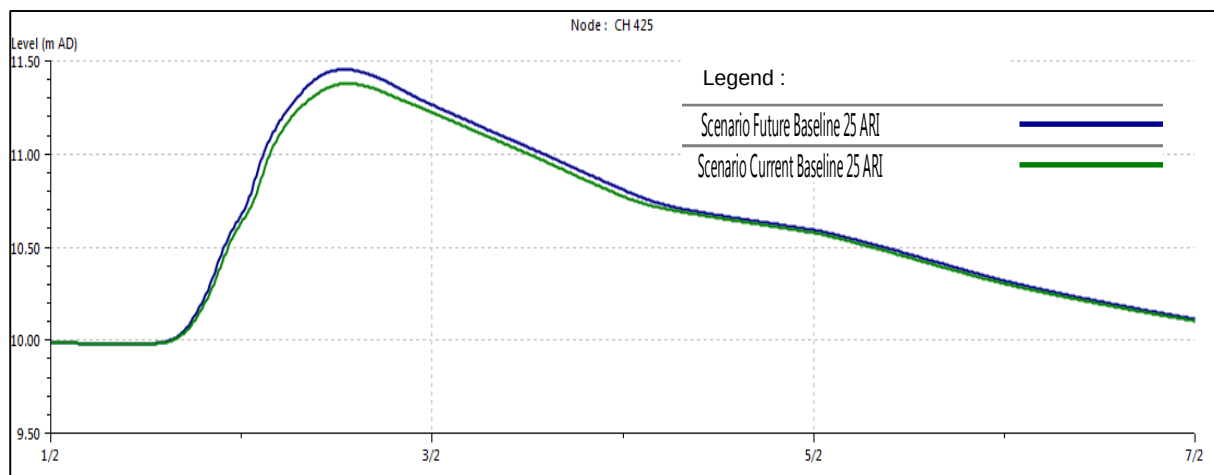


Figure 68: Comparison of water level on the impact of landuse change for 25-year ARI at CH425 Weir Downstream

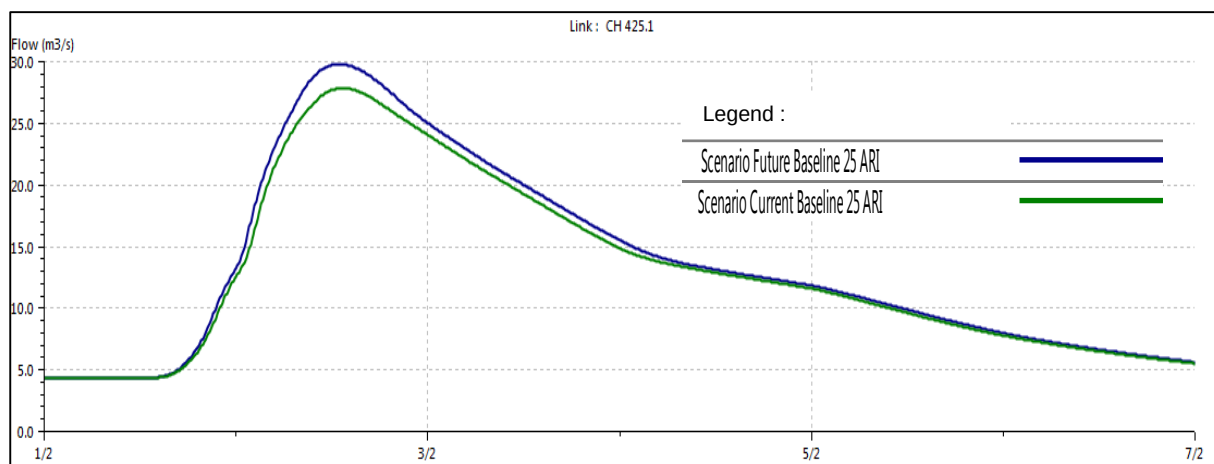


Figure 69: Comparison of flow on the impact of landuse change for 25-year ARI at CH425 Weir Downstream

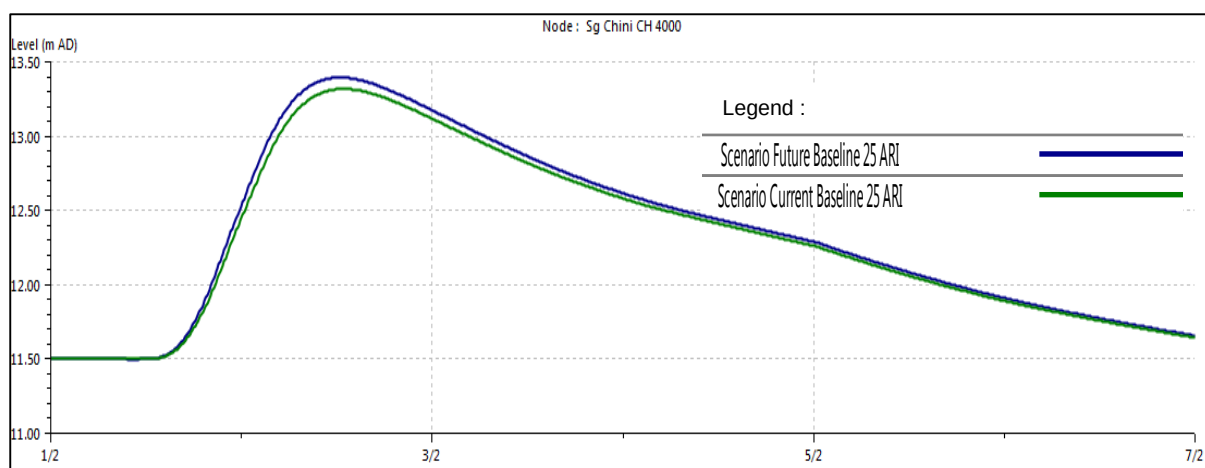


Figure 70: Comparison of water level on the impact of landuse change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

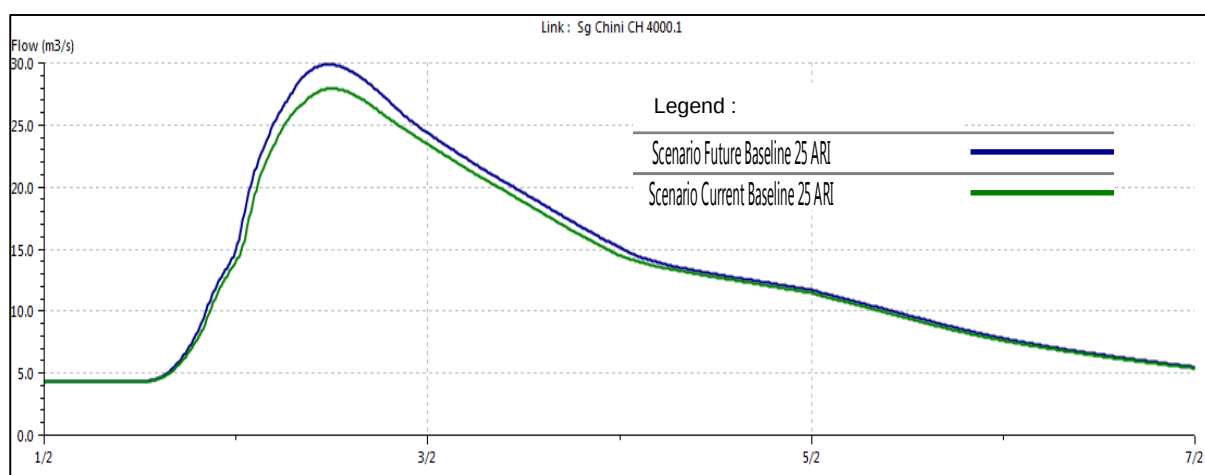


Figure 71: Comparison of flow on the impact of landuse change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 18: Assessment on the impact of landuse change for 50-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current Landuse	Future Landuse	Differences (m/%)	Current Landuse	Future Landuse	Differences (m ³ /s/%)
	50-year	50-year		50-year	50-year	
CH 425 (Weir Upstream)	11.846	11.930	+0.084 (0.709%)	18.306	19.456	+1.150 (6.282%)
CH 425 (Weir Downstream)	11.704	11.782	+0.078 (0.666%)	36.612	38.911	+2.299 (6.279%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.708	13.793	+0.085 (0.620%)	36.756	39.062	+2.306 (6.274%)

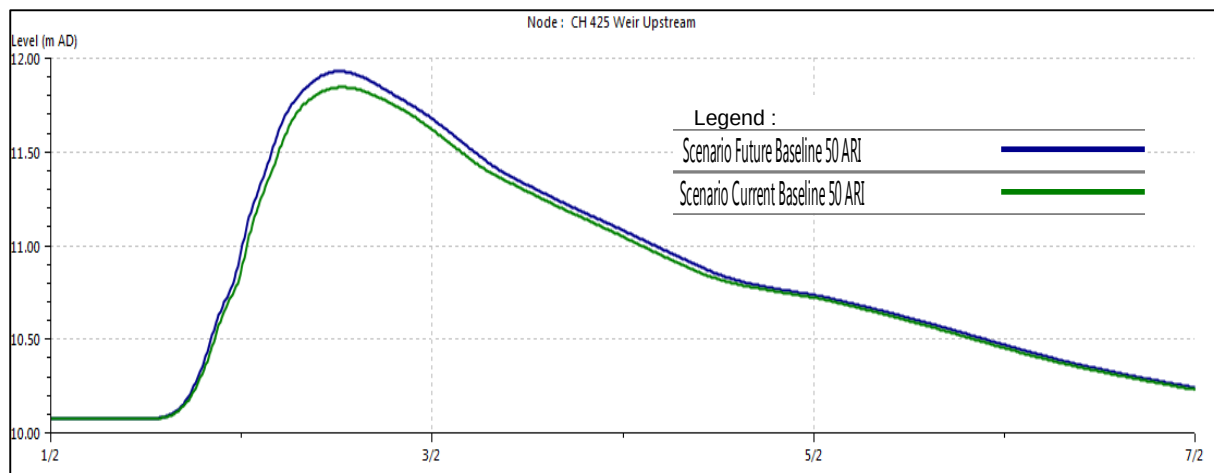


Figure 72: Comparison of water level on the impact of landuse change for 50-year ARI at CH425 Weir Upstream

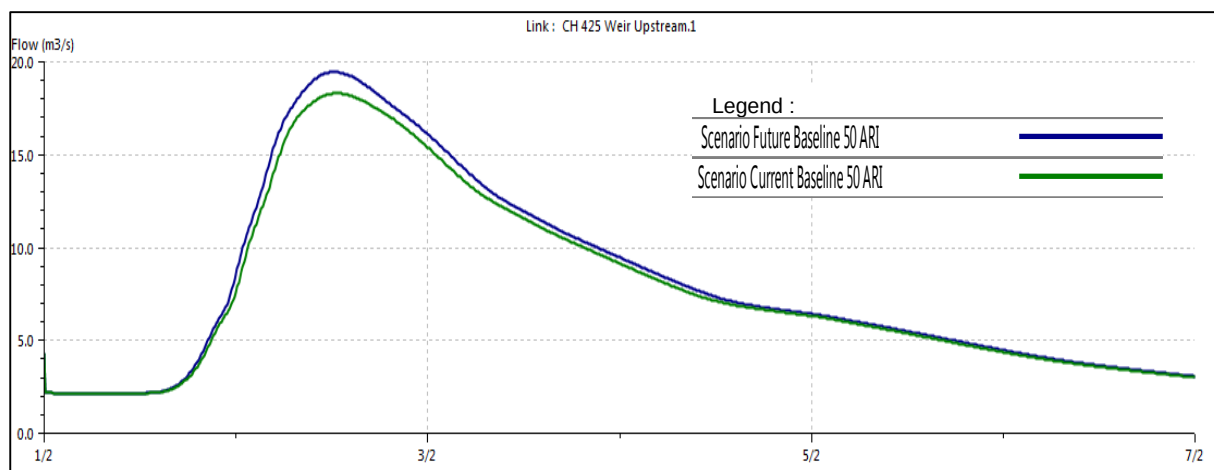


Figure 73: Comparison of flow on the impact of landuse change for 50-year ARI at CH425 Weir Upstream

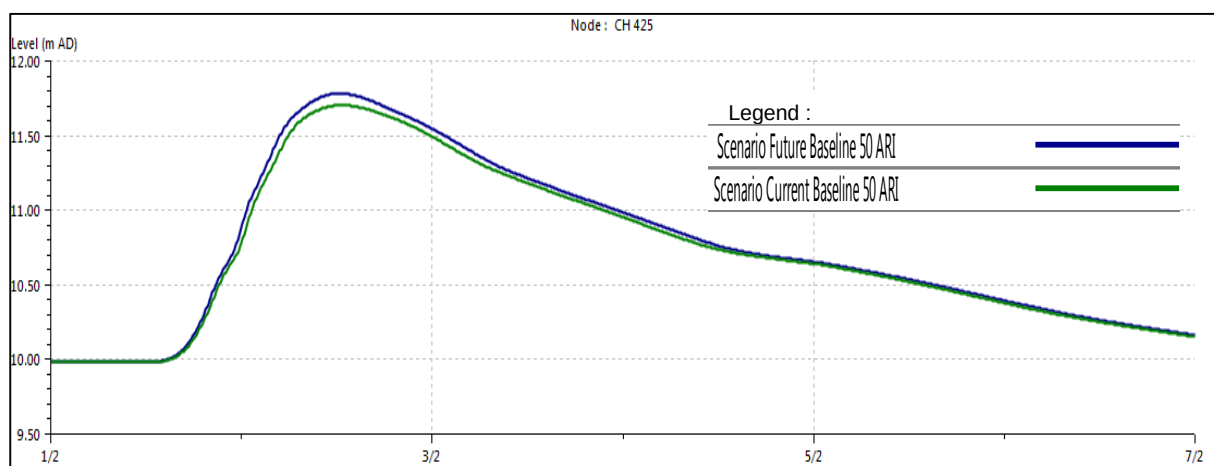


Figure 74: Comparison of water level on the impact of landuse change for 50-year ARI at CH425 Weir Downstream

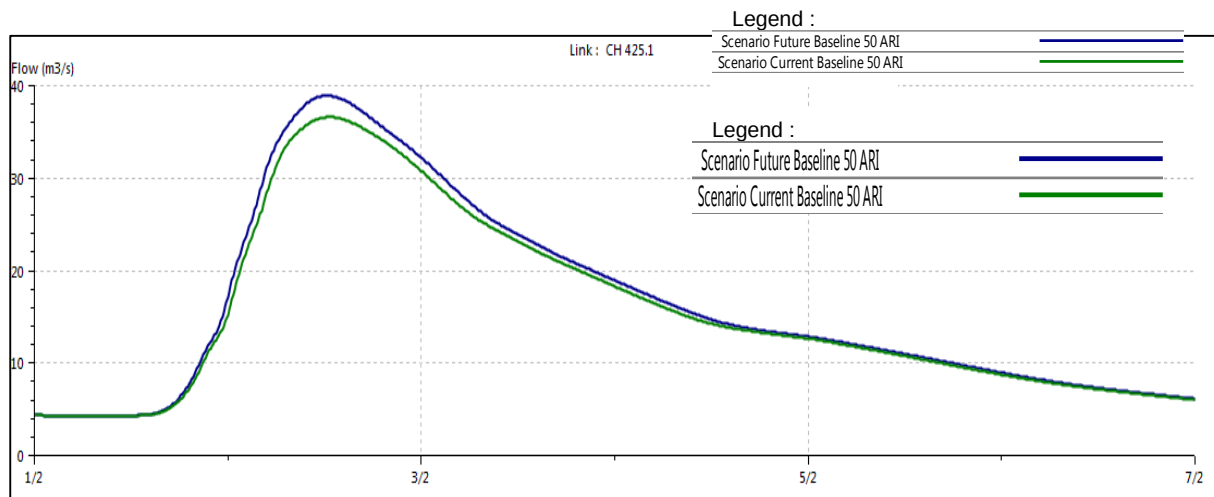


Figure 75: Comparison of flow on the impact of landuse change for 50-year ARI at CH425 Weir Downstream

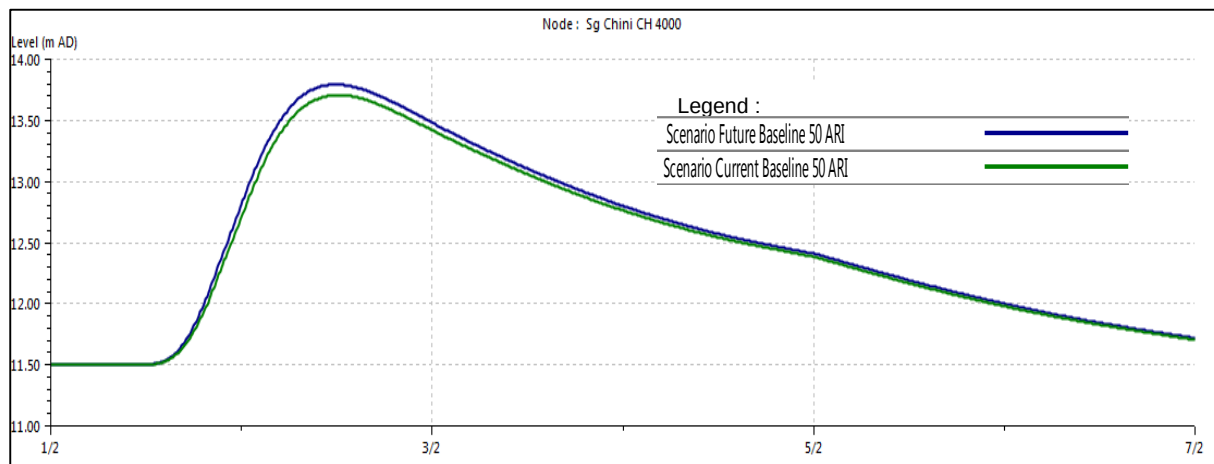


Figure 76: Comparison of water level on the impact of landuse change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

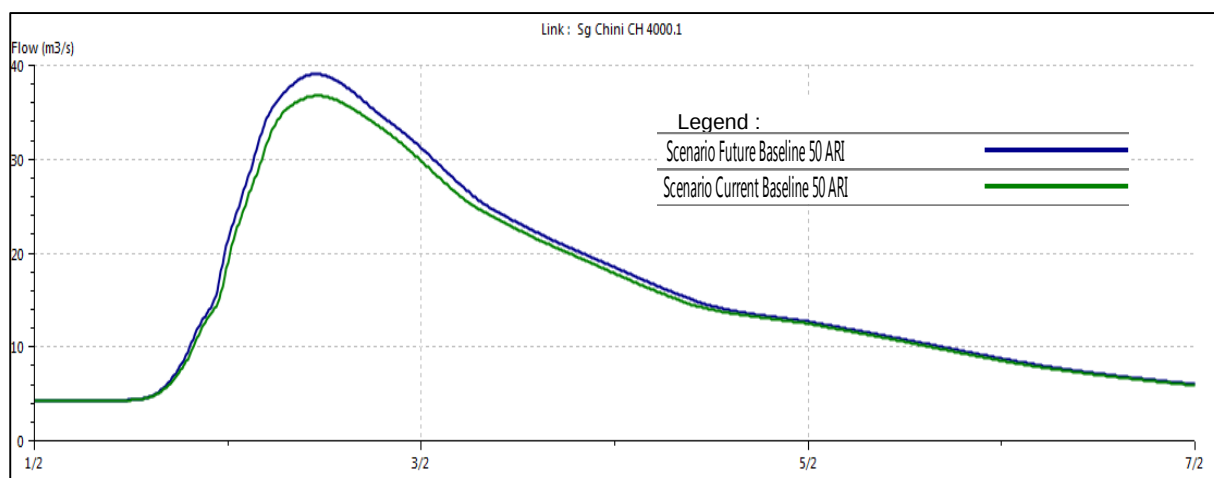


Figure 77: Comparison of flow on the impact of landuse change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 19: Assessment on the impact of landuse change for 100-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current Landuse	Future Landuse	Differences (m/%)	Current Landuse	Future Landuse	Differences (m ³ /s/%)
	100-year	100-year		100-year	100-year	
CH 425 (Weir Upstream)	12.282	12.354	+0.072 (0.586%)	24.687	26.150	+1.463 (5.926%)
CH 425 (Weir Downstream)	12.106	12.168	+0.062 (0.512%)	49.372	52.301	+2.929 (5.933%)
Sg Chini CH 4000 (Upstream of Sg Chini)	14.137	14.227	+0.090 (0.637%)	49.636	52.492	+2.856 (5.754%)

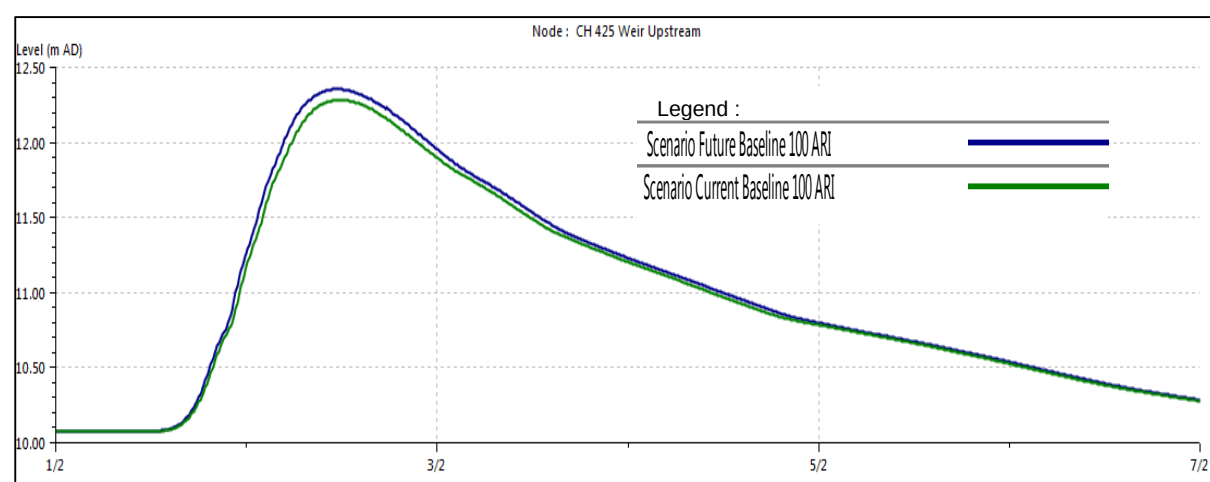


Figure 78: Comparison of water level on the impact of landuse change for 100-year ARI at CH425 Weir Upstream

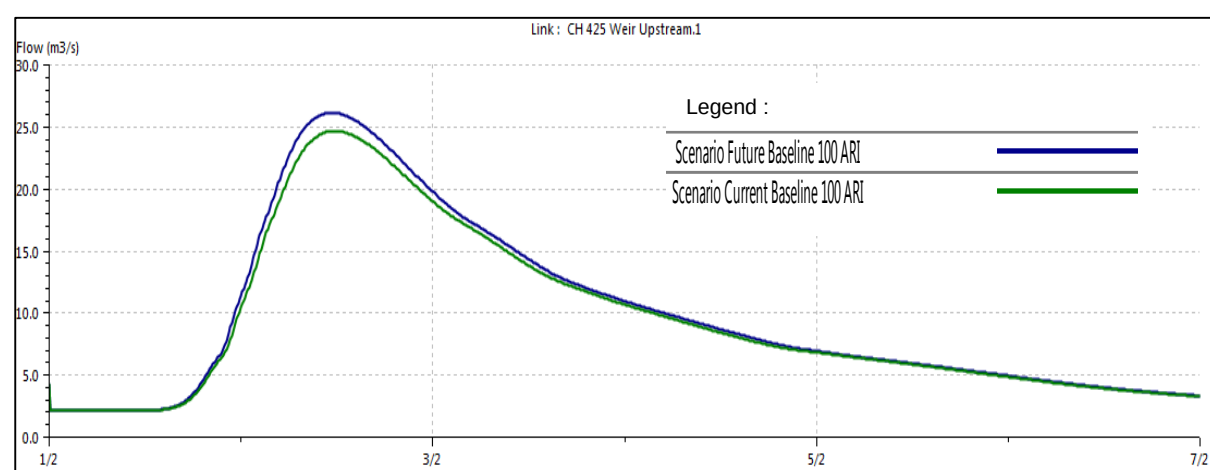


Figure 79: Comparison of flow on the impact of landuse change for 100-year ARI at CH425 Weir Upstream

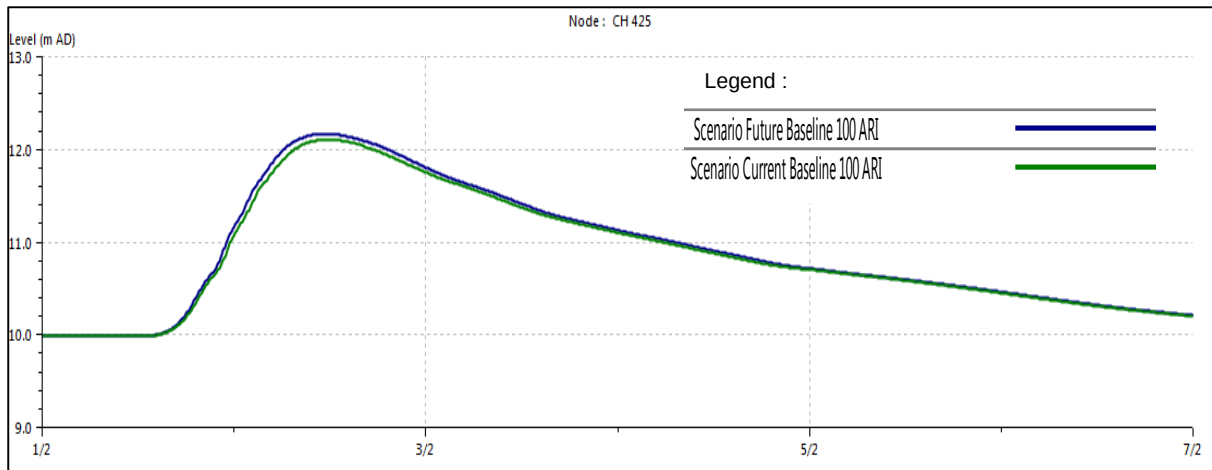


Figure 80: Comparison of water level on the impact of landuse change for 100-year ARI at CH425 Weir Downstream

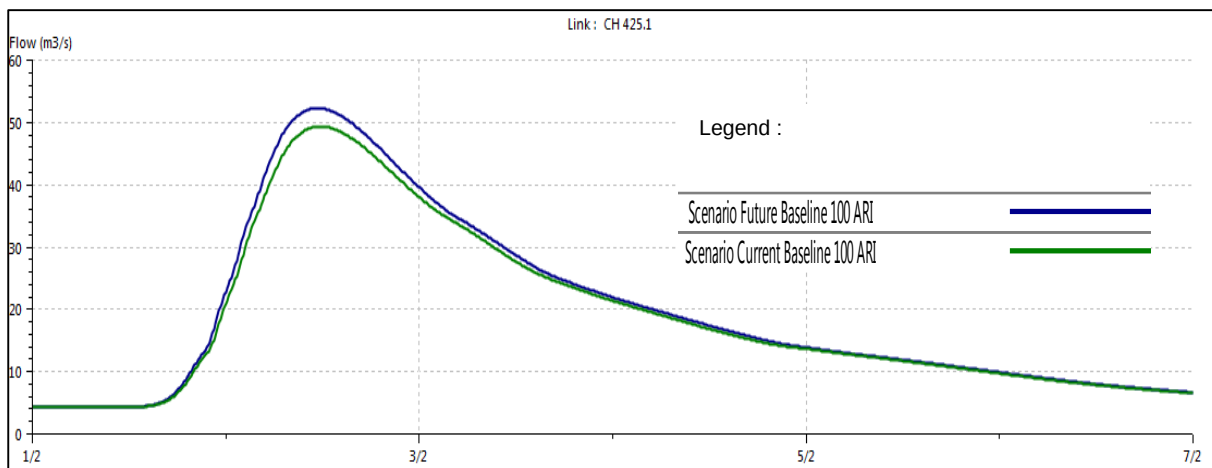


Figure 81: Comparison of flow on the impact of landuse change for 100-year ARI at CH425 Weir Downstream

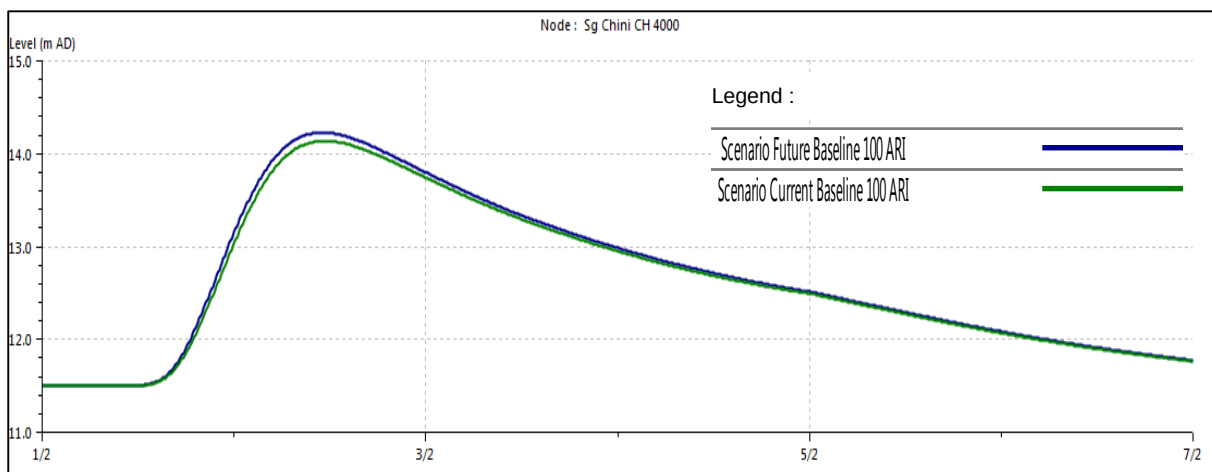


Figure 82: Comparison of water level on the impact of landuse change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

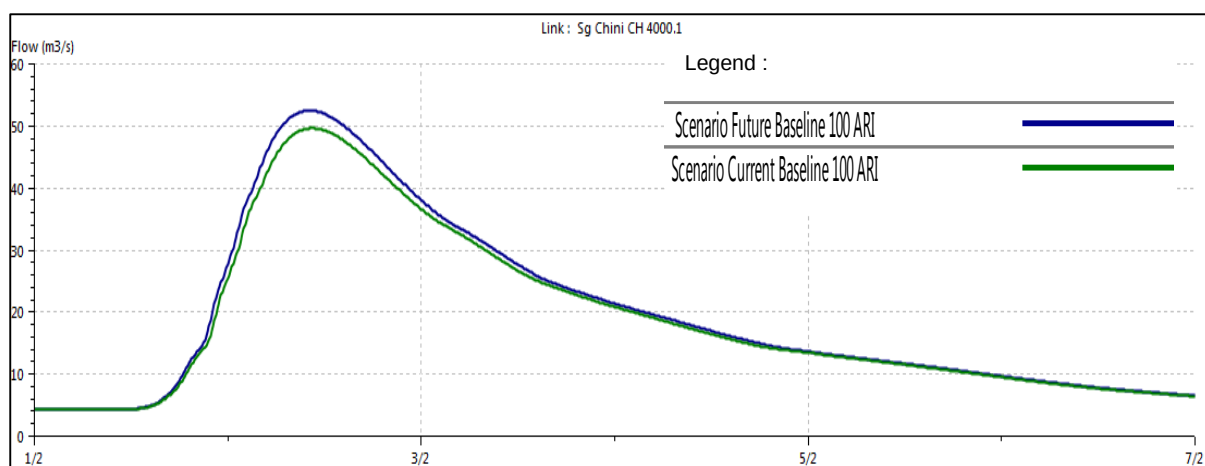


Figure 83: Comparison of flow on the impact of landuse change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

7.2 Impact of Climate Change

An assessment was on the impact of climate change (from baseline to future meteorological event) for various ARIs. The assessment was carried out by comparing the Scenario 1: Current (Landuse) and Baseline (Meteorology) and Scenario 2: Current (Landuse) and Future (Meteorology). Table 20 and Figures 84 to 89 show the assessment on impact of climate change for 10-year ARI, Table 21 and Figures 90 to 95 show the assessment on the impact of climate change for 20-year ARI, Table 22 and Figures 96 to 101 show the assessment on the impact of climate change for 25-year ARI, Table 23 and Figures 102 to 107 show the assessment on the impact of climate change for 50-year ARI and Table 24 and Figures 108 to 113 show the assessment on the impact of climate change for 100-year ARI.

Basically, the results show a higher increment in both water level and flow for various ARIs under the impact of climate change with increase of 0.849 m (7.699%) to 1.903 m (13.461%) for water level and major increase of 11.003 m³/s (111.141%) to 80.755 m³/s (162.690%) for flow. At particular location at CH 425 (Weir Upstream), the results depicted higher water level from 0.907 m (8.153%) to 1.846 m (15.030%) and higher flow from 11.003m³/s (111.141%) to 40.356 m³/s (163.470%). At CH 425 (Weir Downstream), the results show an increment from 0.849 m (7.699%) to 1.524 m (13.021%) in water level, while increment ranging from 22.006 m³/s (111.147%) to 80.714 m³/s (163.480%) for flow. The results also demonstrated an increment ranging from 1.029 m (8.000%) to 1.903 m (13.461%) in water level, while increment ranging from 22.123 m³/s (111.473%) to 80.755 m³/s (162.690%) at Sg Chini CH 4000 (Upstream of Sg Chini).

Table 20: Assessment on the impact of climate change for 10-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current (Meteorology)	Future (Meteorology)	Differences (m/%)	Current (Meteorology)	Future (Meteorology)	Differences (m ³ /s/%)
	10-year	10-year		10-year	10-year	
CH 425 (Weir Upstream)	11.125	12.032	+0.907 (8.153 %)	9.900	20.903	+11.003 (111.141 %)
CH 425 (Weir Downstream)	11.028	11.877	+0.849 (7.699 %)	19.799	41.805	+22.006 (111.147 %)
Sg Chini CH 4000 (Upstream of Sg Chini)	12.863	13.892	+1.029 (8.000%)	19.846	41.969	+22.123 (111.473%)

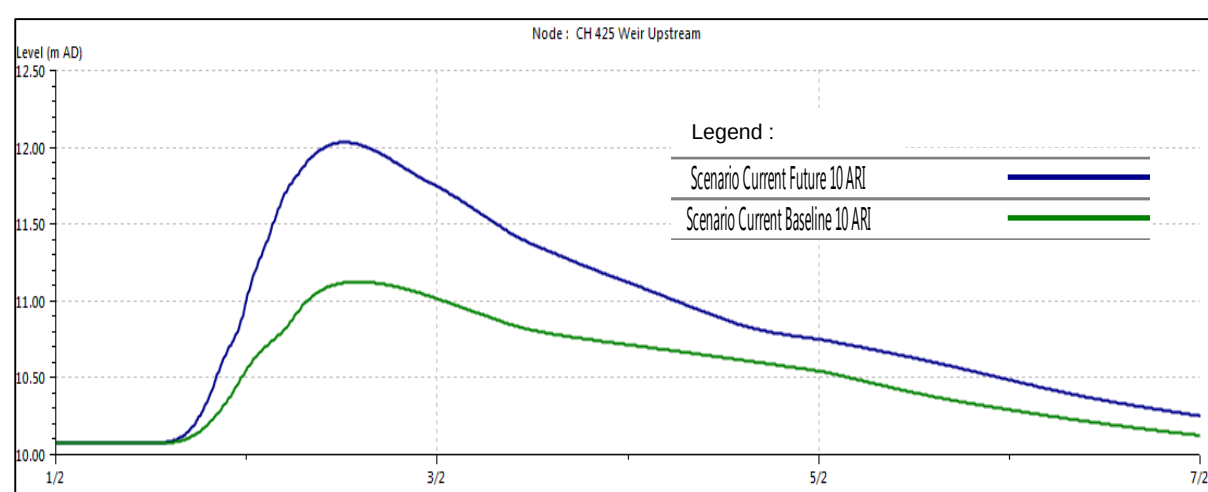


Figure 84: Comparison of water level on the impact of climate change for 10-year ARI at CH425 Weir Upstream

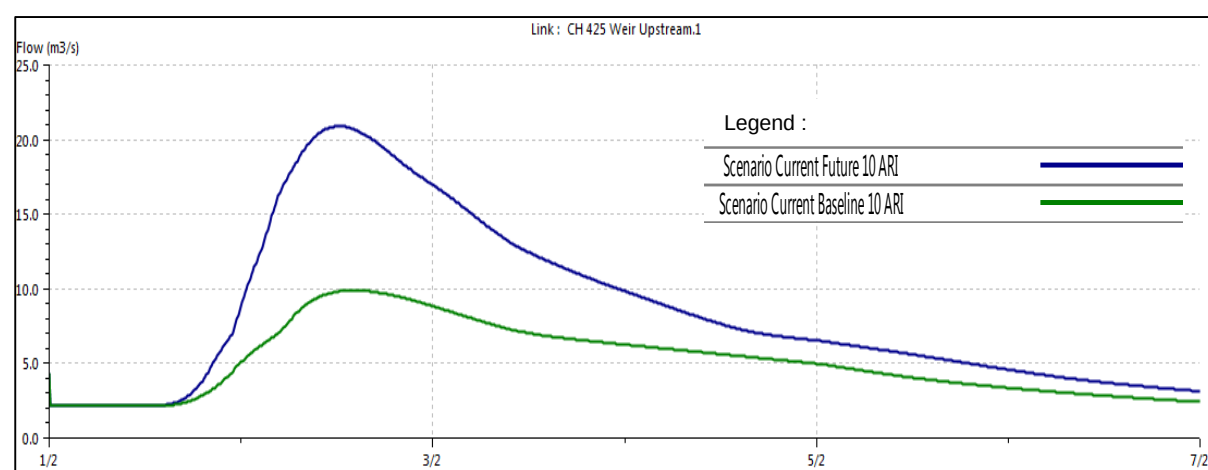


Figure 85: Comparison of flow on the impact of climate change for 10-year ARI at CH425 Weir Upstream

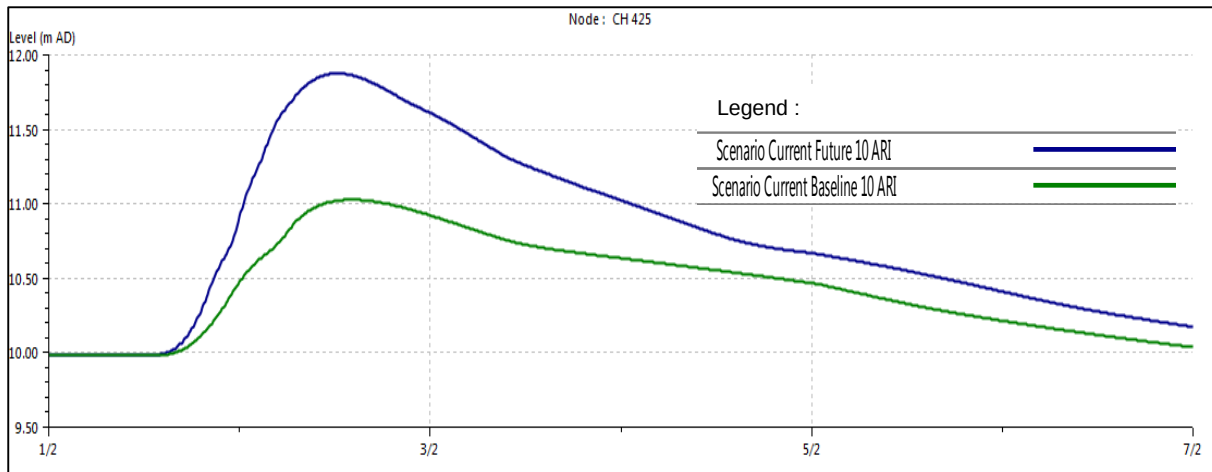


Figure 86: Comparison of water level on the impact of climate change for 10-year ARI at CH425 Weir Downstream

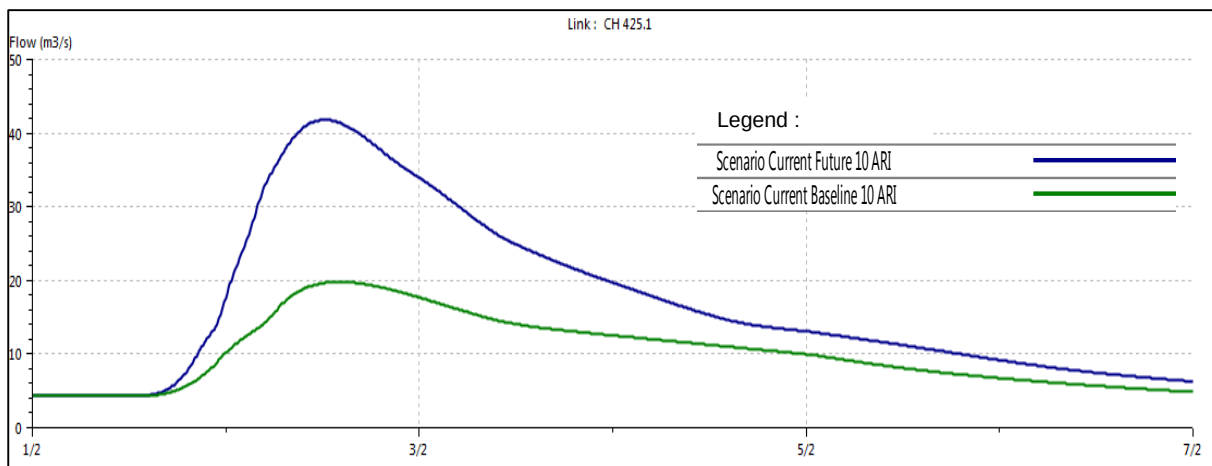


Figure 87: Comparison of flow on the impact of climate change for 10-year ARI at CH425 Weir Downstream

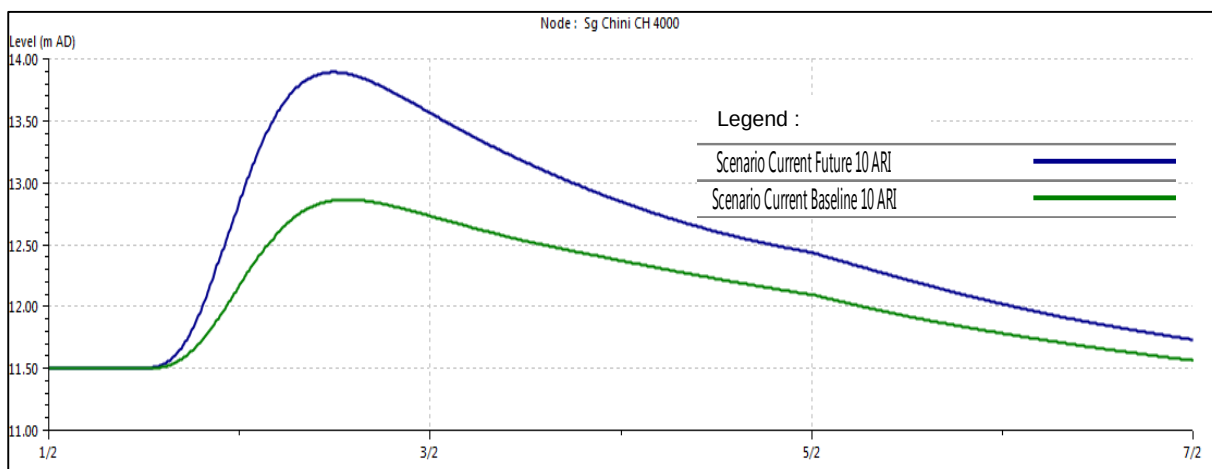


Figure 88: Comparison of water level on the impact of climate change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

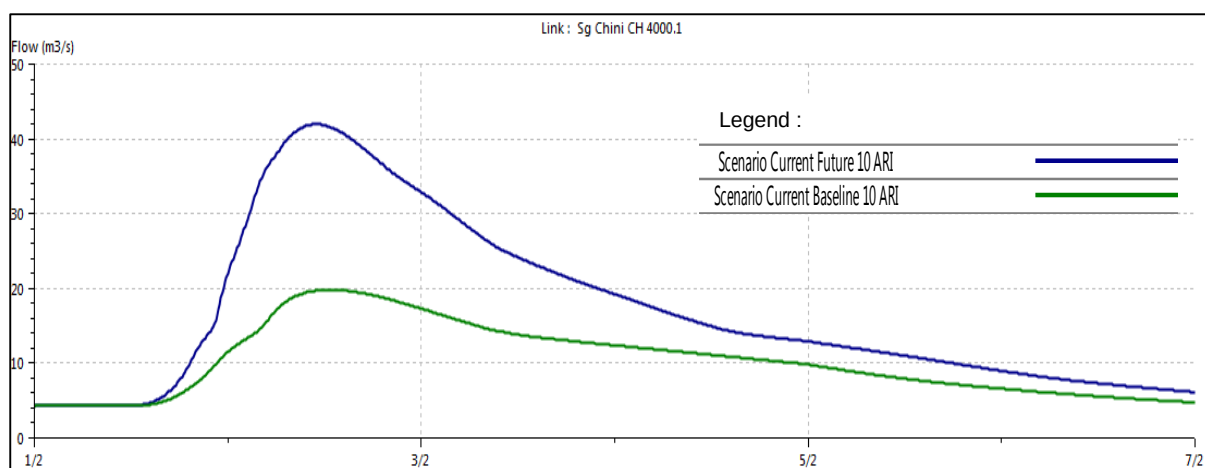


Figure 89: Comparison of flow on the impact of climate change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 21: Assessment on the impact of climate change for 20-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m³/s		
	Current (Meteorology)	Future (Meteorology)	Differences (m/%)	Current (Meteorology)	Future (Meteorology)	Differences (m³/s/%)
	20-year	20-year		20-year	20-year	
CH 425 (Weir Upstream)	11.386	12.574	+1.188 (10.434%)	12.641	30.161	+17.52 (138.597%)
CH 425 (Weir Downstream)	11.274	12.363	+1.089 (9.659%)	25.282	60.321	+35.039 (138.593%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.202	14.464	+1.262 (9.559%)	25.366	60.523	+35.157 (138.599%)

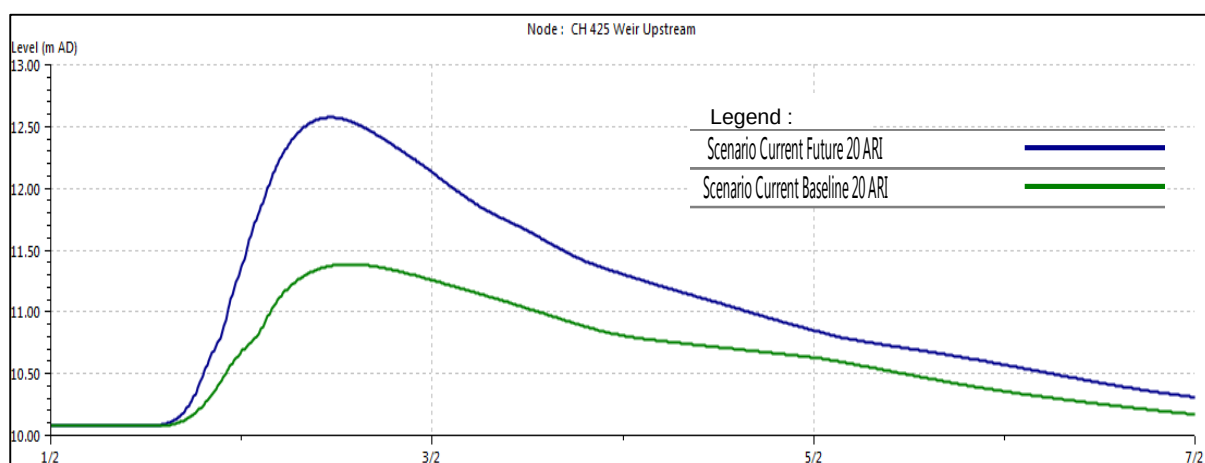


Figure 90: Comparison of water level on the impact of climate change for 20-year ARI at CH425 Weir Upstream

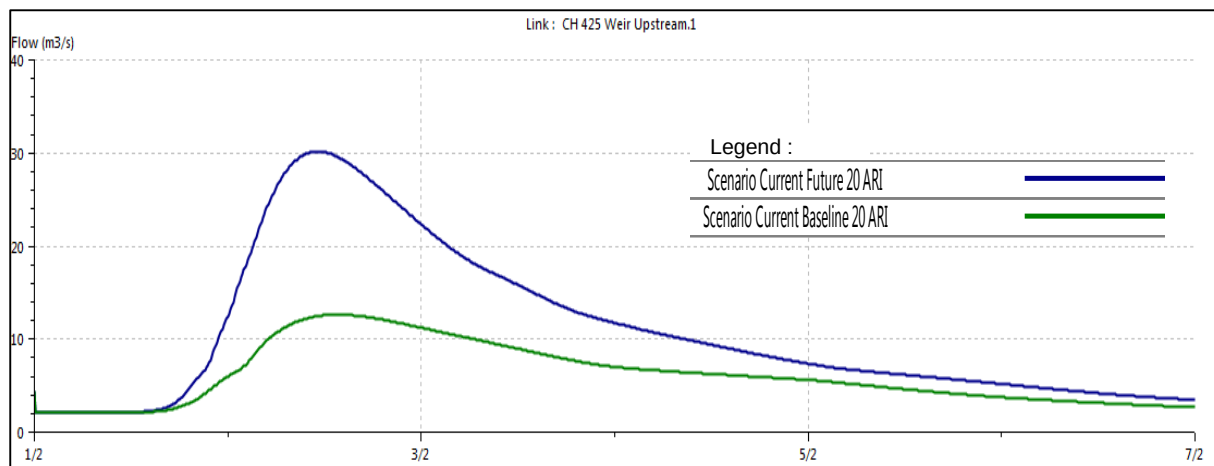


Figure 91: Comparison of flow on the impact of climate change for 20-year ARI at CH425 Weir Upstream

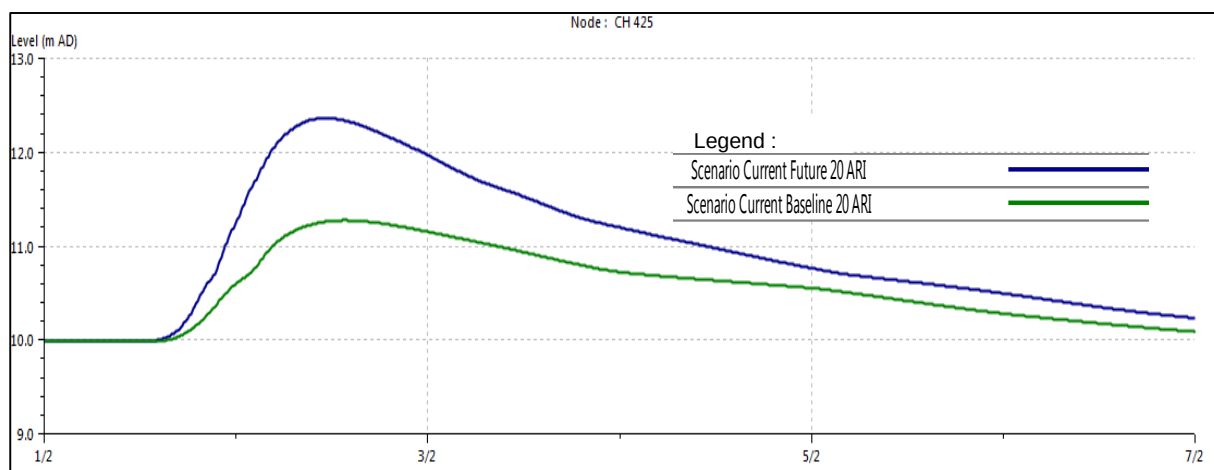


Figure 92: Comparison of water level on the impact of climate change for 20-year ARI at CH425 Weir Downstream

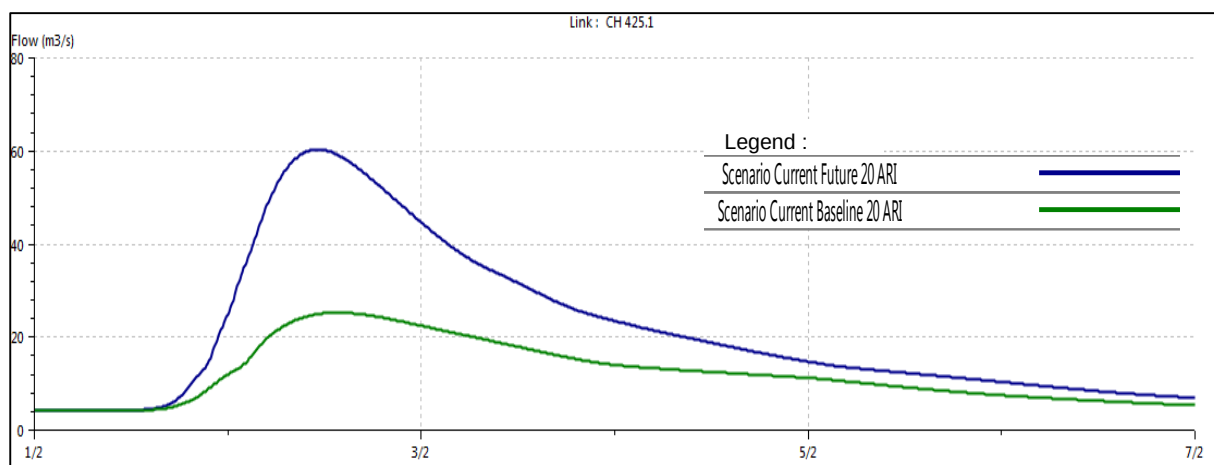


Figure 93: Comparison of flow on the impact of climate change for 20-year ARI at CH425 Weir Downstream

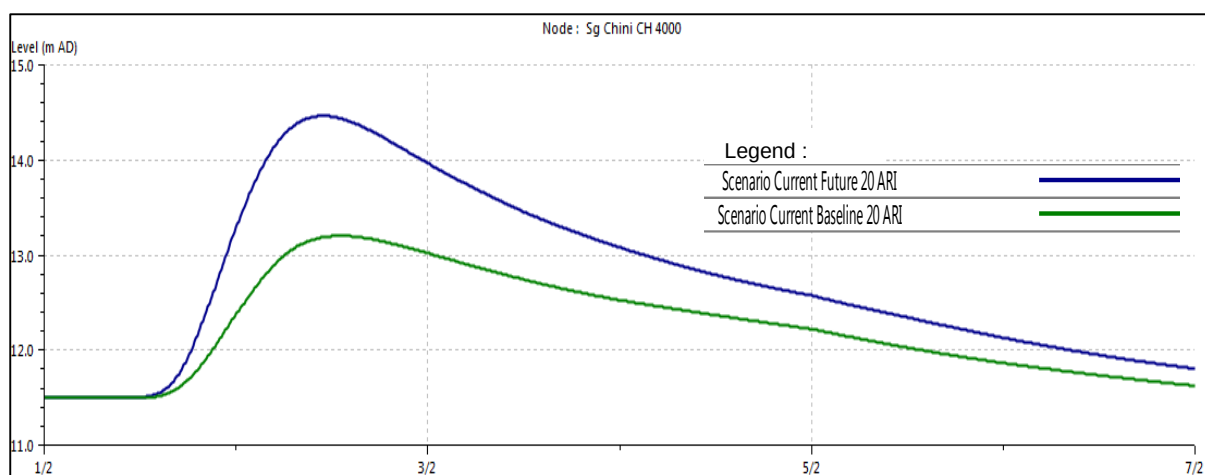


Figure 94: Comparison of water level on the impact of climate change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

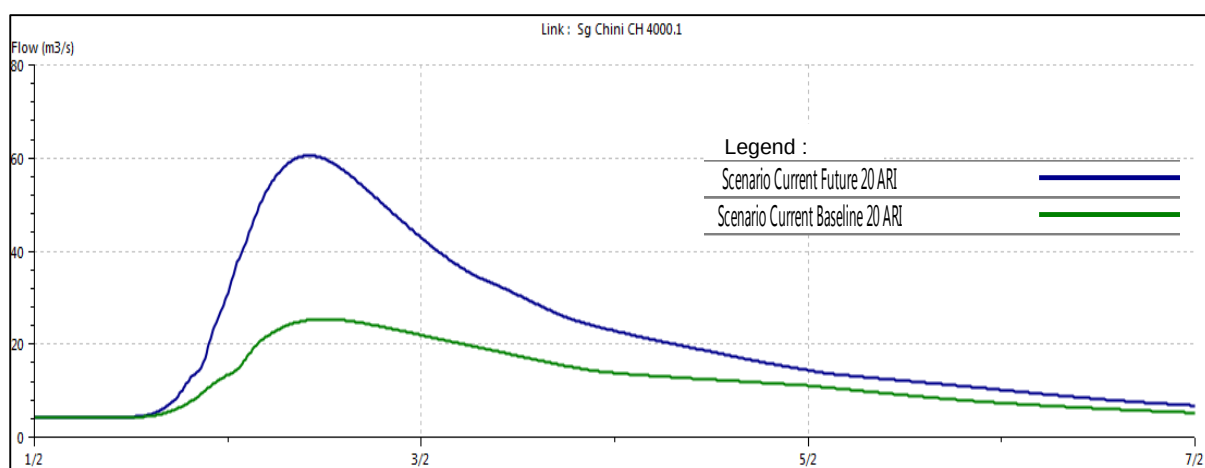


Figure 95: Comparison of flow on the impact of climate change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 22: Assessment on the impact of climate change for 25-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current (Meteorology)	Future (Meteorology)	Differences (m/%)	Current (Meteorology)	Future (Meteorology)	Differences (m ³ /s/%)
	25-year	25-year		25-year	25-year	
CH 425 (Weir Upstream)	11.497	12.840	+1.343 (11.681%)	13.926	35.506	+21.58 (154.962%)
CH 425 (Weir Downstream)	11.379	12.597	+1.218 (10.704%)	27.851	71.012	+43.161 (154.971%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.318	14.749	+1.431 (10.745%)	27.942	71.137	+43.195 (154.588%)

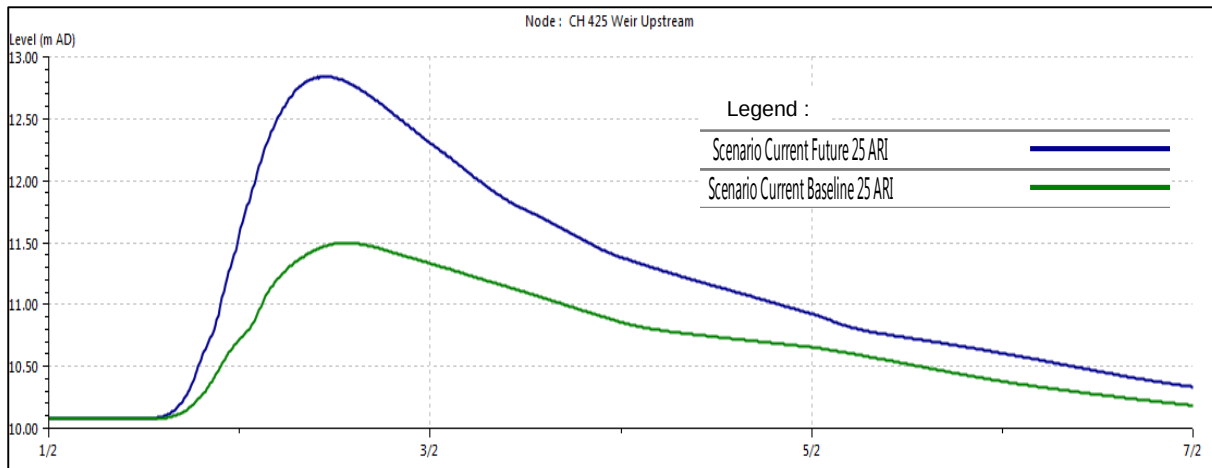


Figure 96: Comparison of water level on the impact of climate change for 25-year ARI at CH425 Weir Upstream

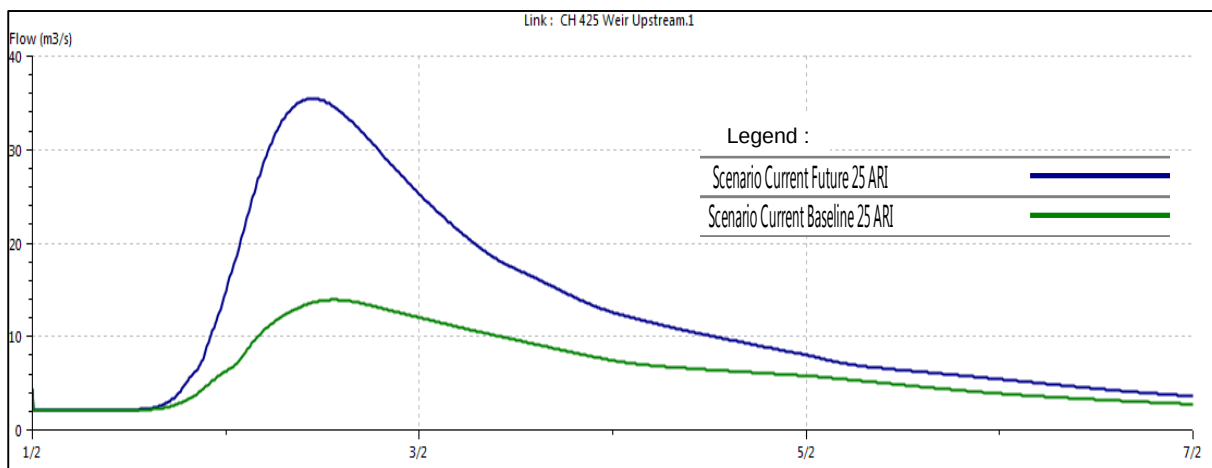


Figure 97: Comparison of flow on the impact of climate change for 25-year ARI at CH425 Weir Upstream

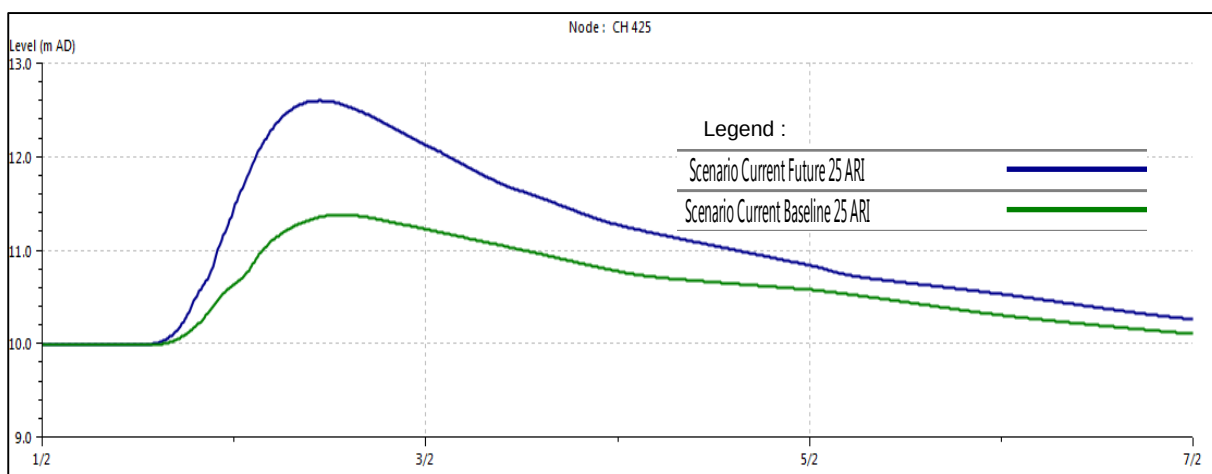


Figure 98: Comparison of water level on the impact of climate change for 25-year ARI at CH425 Weir Downstream

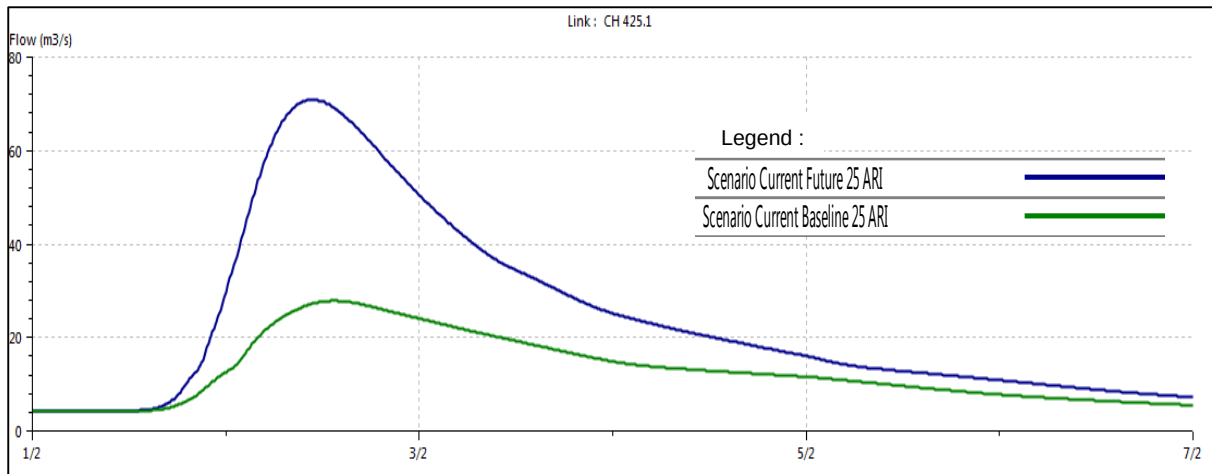


Figure 99: Comparison of flow on the impact of climate change for 25-year ARI at CH425 Weir Downstream

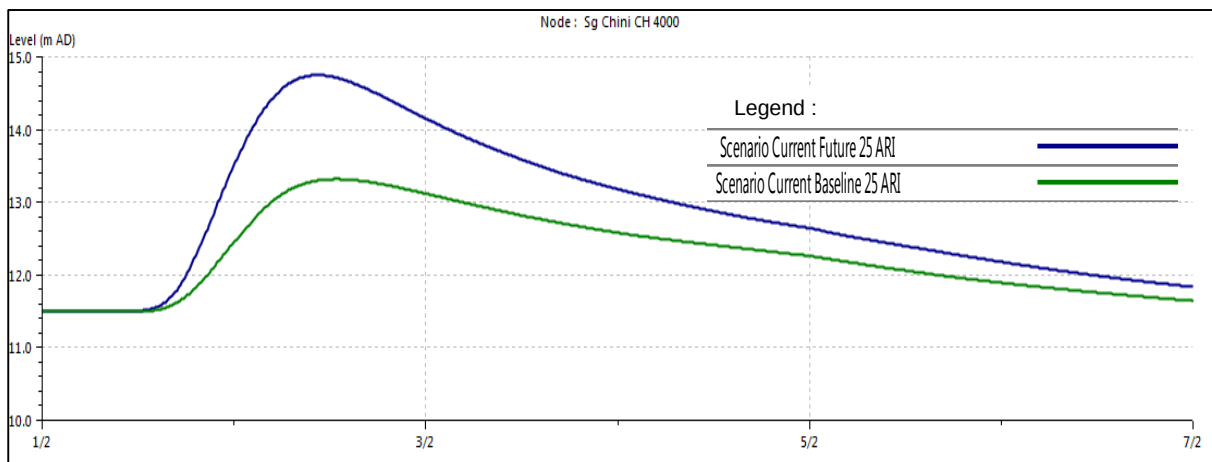


Figure 100: Comparison of water level on the impact of climate change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

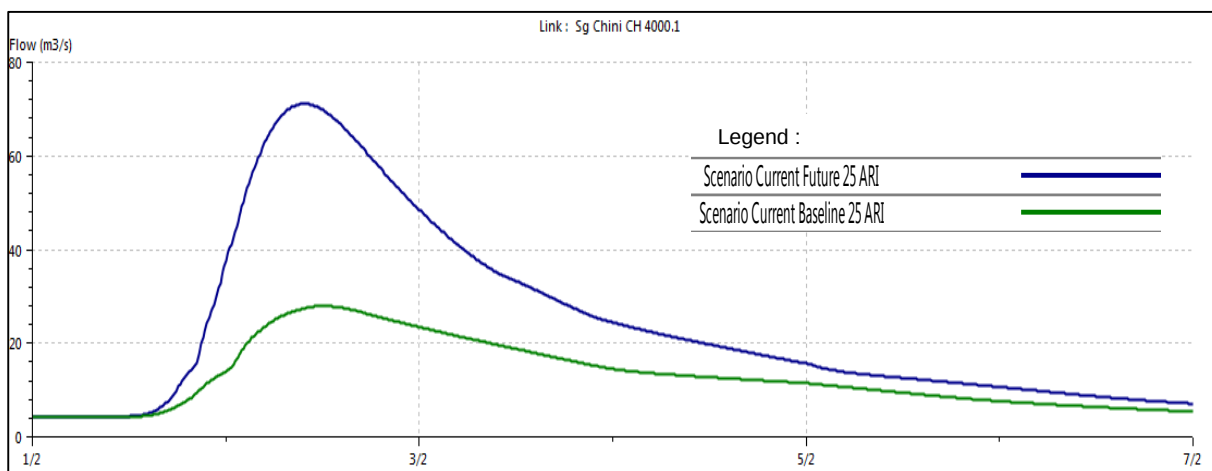


Figure 101: Comparison of flow on the impact of climate change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 23: Assessment on the impact of climate change for 50-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current (Meteorology)	Future (Meteorology)	Differences (m/%)	Current (Meteorology)	Future (Meteorology)	Differences (m ³ /s/%)
	50-year	50-year		50-year	50-year	
CH 425 (Weir Upstream)	11.846	13.546	+1.7 (14.351%)	18.306	50.030	+31.724 (173.298%)
CH 425 (Weir Downstream)	11.704	13.228	+1.524 (13.021%)	36.612	100.060	+63.448 (173.298%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.708	15.430	+1.722 (12.562%)	36.756	100.251	+63.495 (172.747%)

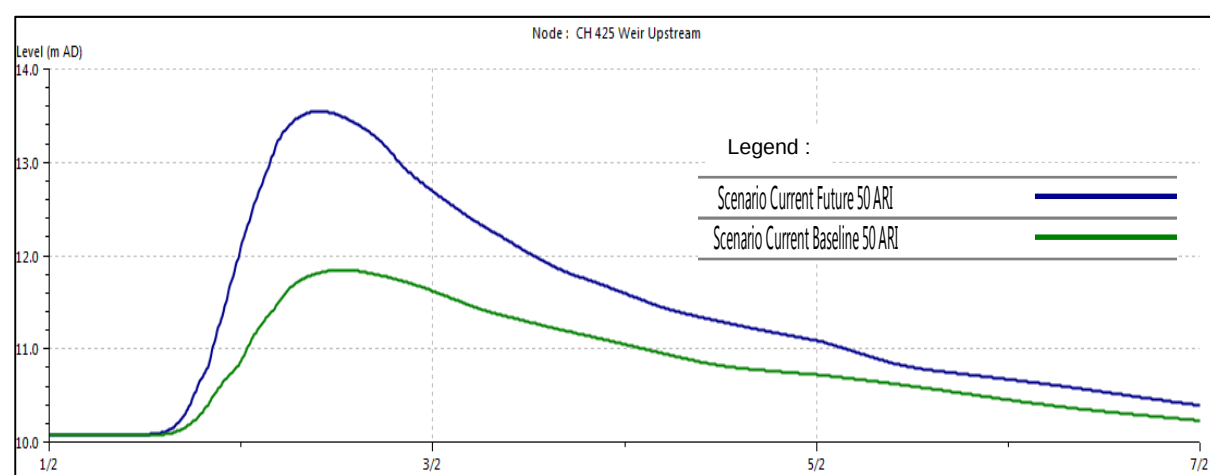


Figure 102: Comparison of water level on the impact of climate change for 50-year ARI at CH425 Weir Upstream

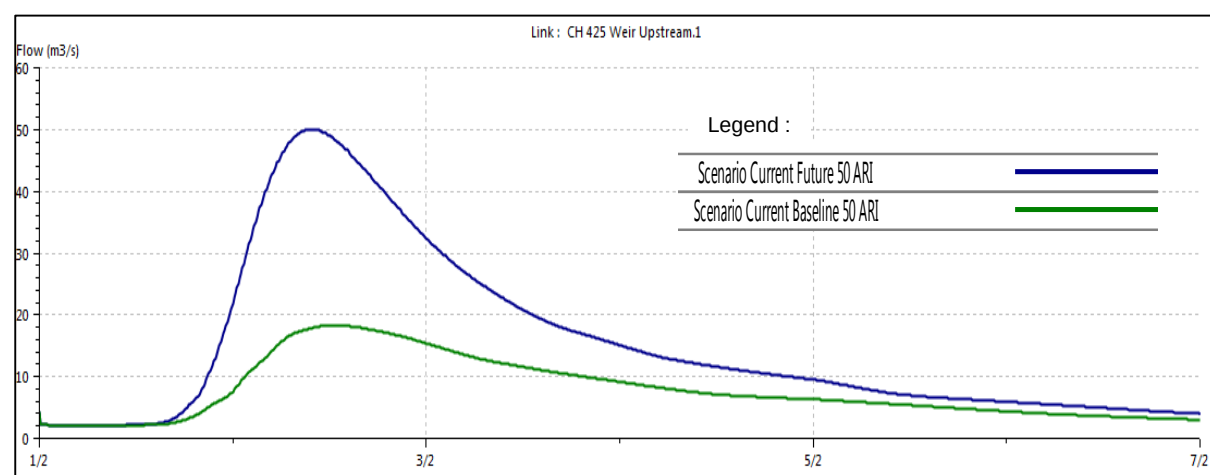


Figure 103: Comparison of flow on the impact of climate change for 50-year ARI at CH425 Weir Upstream

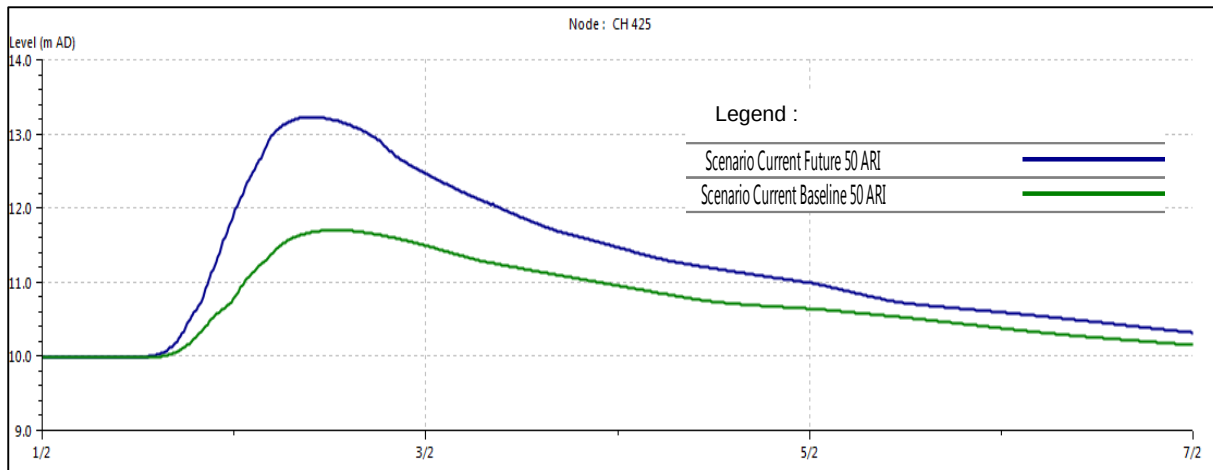


Figure 104: Comparison of water level on the impact of climate change for 50-year ARI at CH425 Weir Downstream

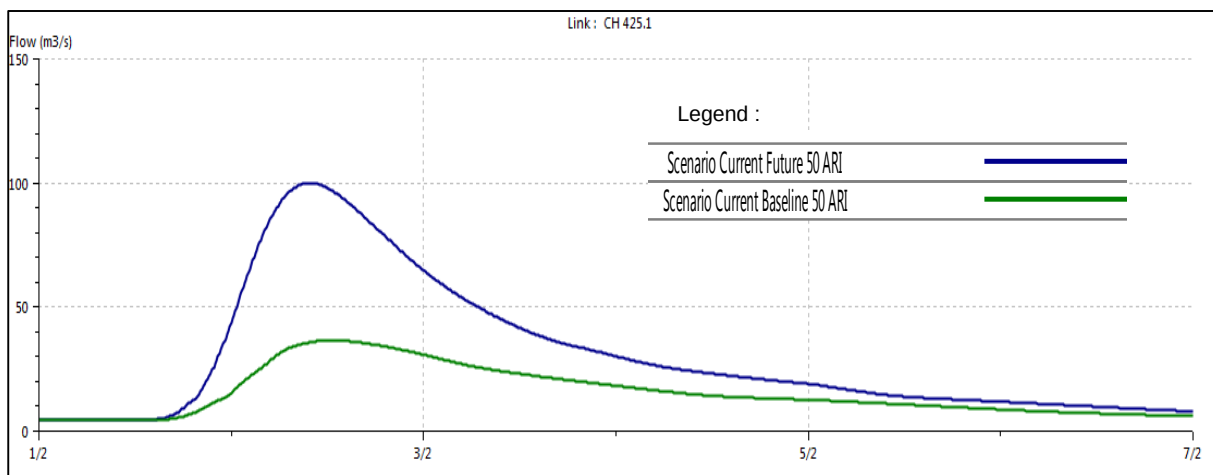


Figure 105: Comparison of flow on the impact of climate change for 50-year ARI at CH425 Weir Downstream

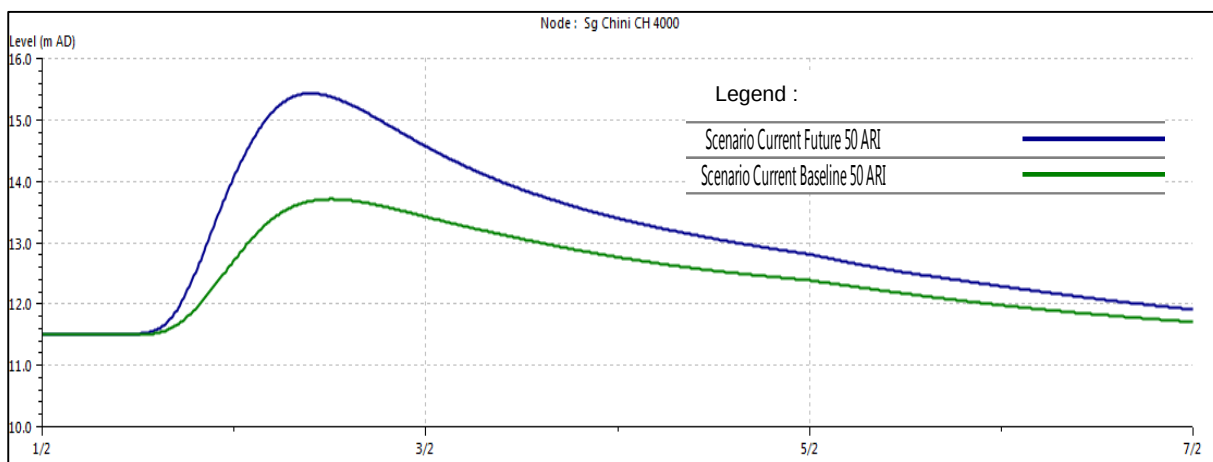


Figure 106: Comparison of water level on the impact of climate change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

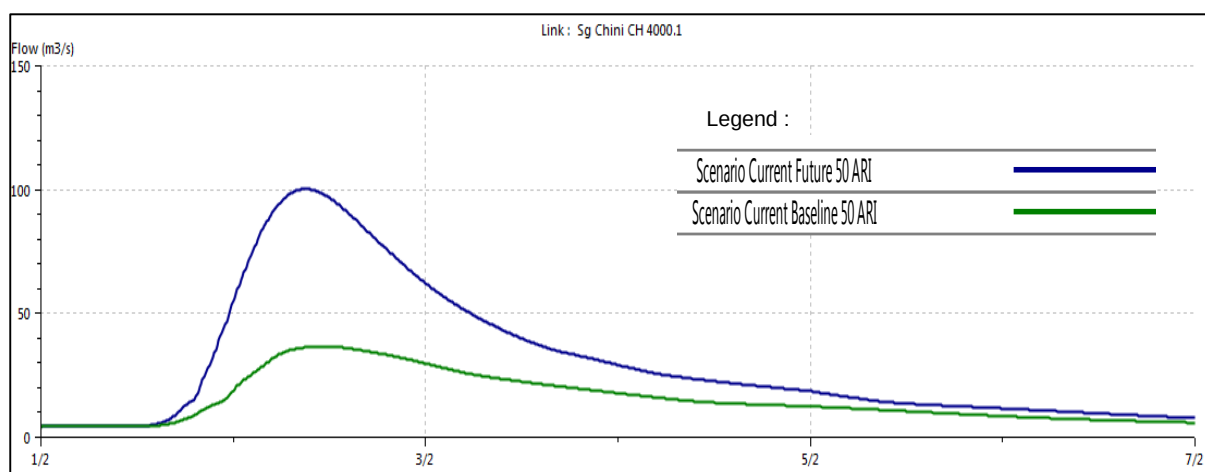


Figure 107: Comparison of flow on the impact of climate change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 24 : Assessment on the impact of climate change for ARI 100-year

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m³/s		
	Current (Meteorology)	Future (Meteorology)	Differences (m/%)	Current (Meteorology)	Future (Meteorology)	Differences (m³/s/%)
	100-year	100-year		100-year	100-year	
CH 425 (Weir Upstream)	12.282	14.128	+1.846 (15.030%)	24.687	65.043	+40.356 (163.471%)
CH 425 (Weir Downstream)	12.106	13.273	+1.167 (9.640%)	49.372	130.086	+80.714 (163.481%)
Sg Chini CH 4000 (Upstream of Sg Chini)	14.137	16.040	+1.903 (13.461%)	49.636	130.391	+80.755 (162.694%)

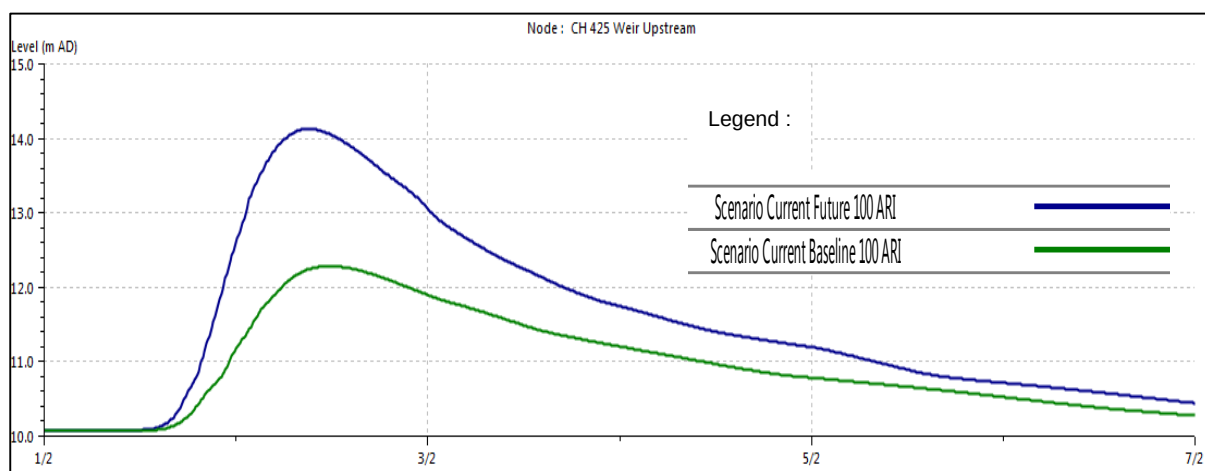


Figure 108: Comparison of water level on the impact of climate change for 100-year ARI at CH425 Weir Upstream

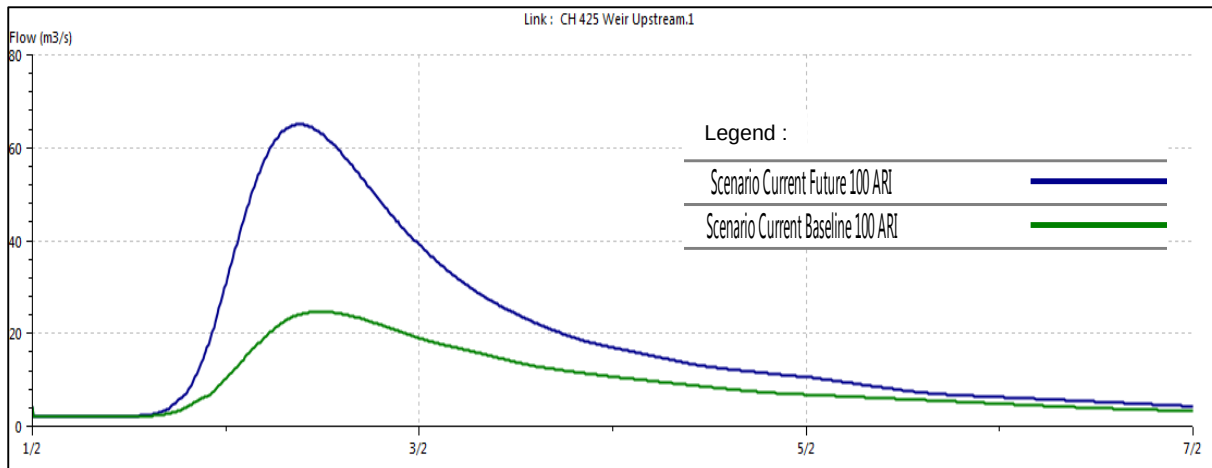


Figure 109: Comparison of flow on the impact of climate change for 100-year ARI at CH425 Weir Upstream

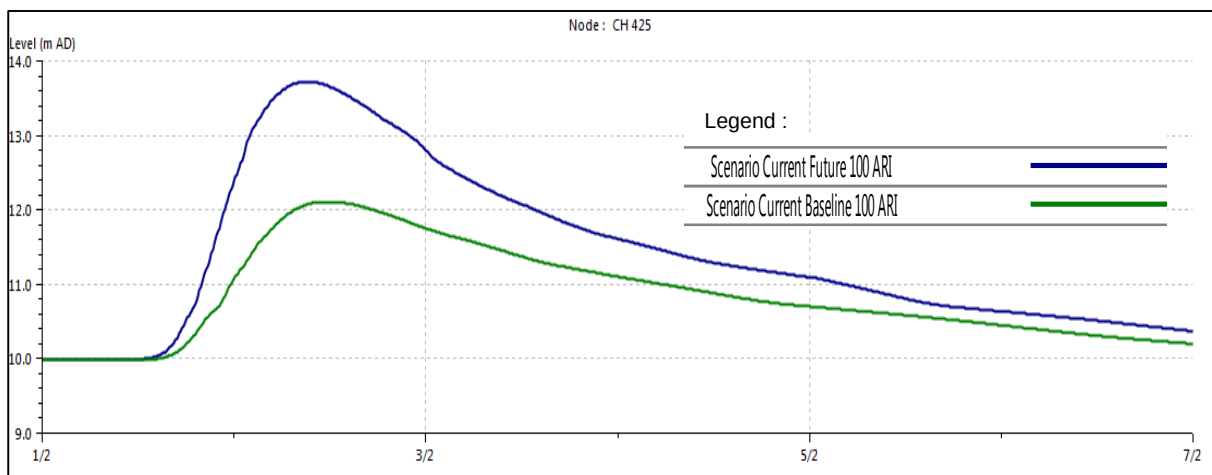


Figure 110: Comparison of water level on the impact of climate change for 100-year ARI at CH425 Weir Downstream

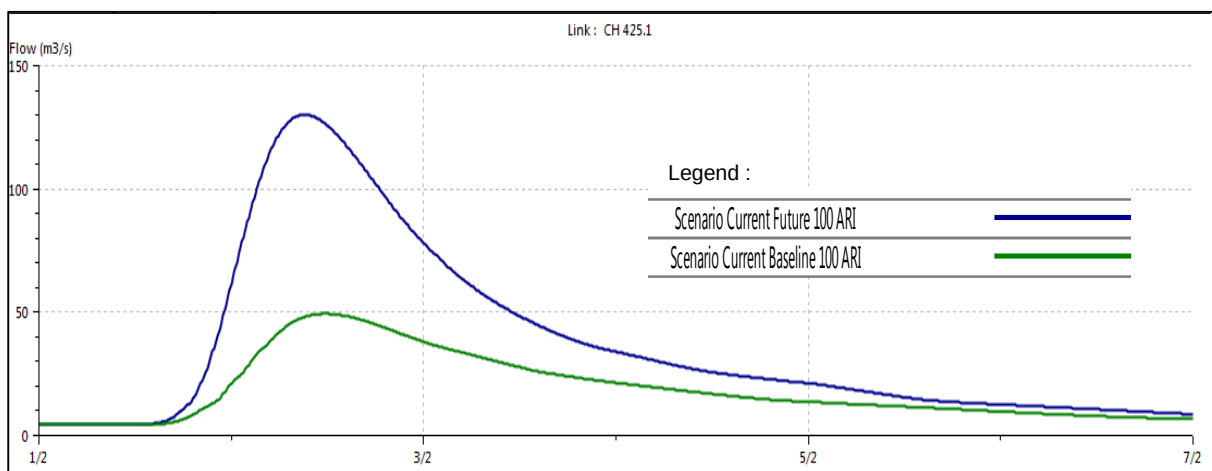


Figure 111: Comparison of flow on the impact of climate change for 100-year ARI at CH425 Weir Downstream

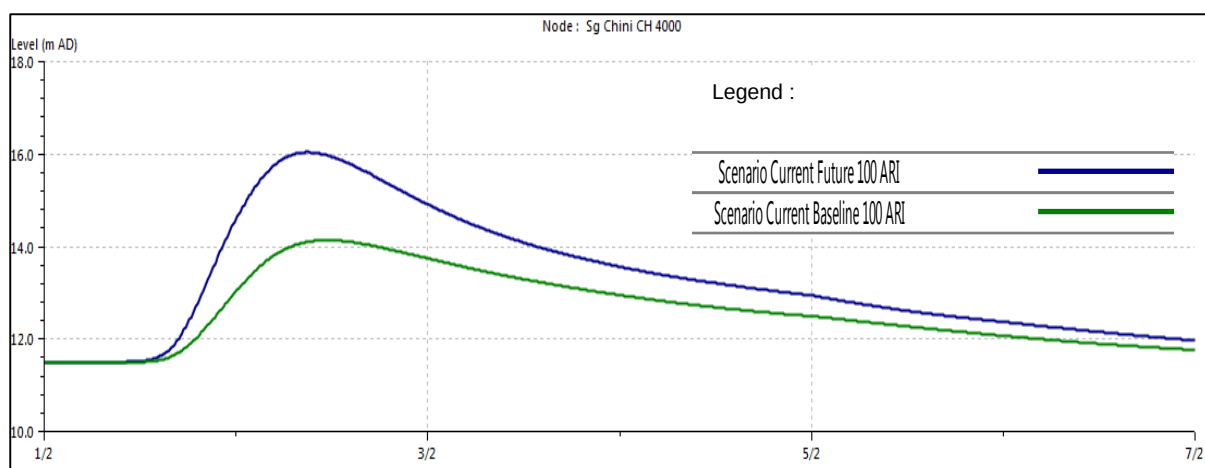


Figure 112: Comparison of water level on the impact of climate change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

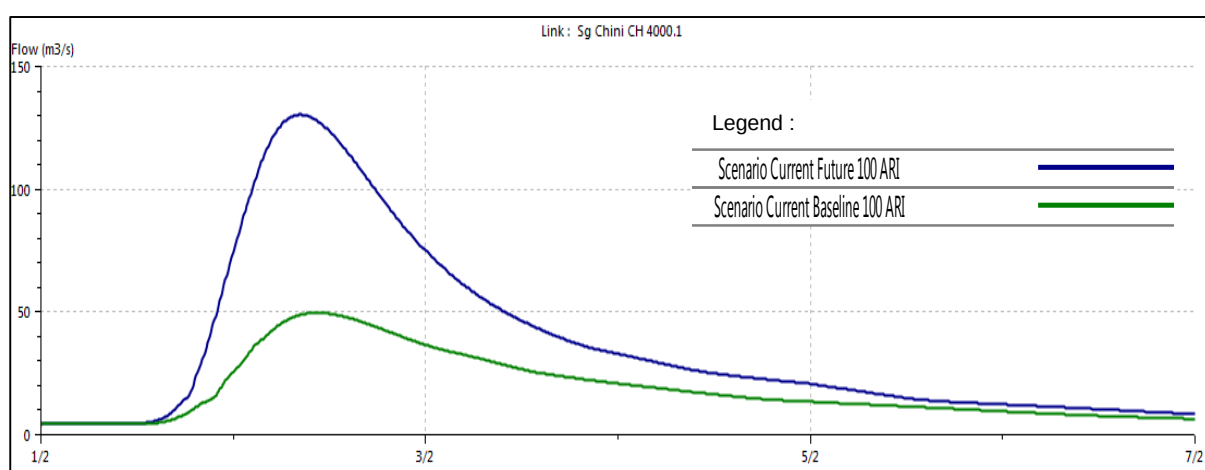


Figure 113: Comparison of flow on the impact of climate change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

7.3 Combination of the Impact of Landuse and Climate Change

An assessment was also done on the combination of the impact of landuse and climate change for various ARIs. The assessment was carried out by comparing the Scenario 1: Current (Landuse) and Baseline (Meteorology) and Scenario 4: Future (Landuse) and Future (Meteorology). Table 25 and Figures 114 to 119 show the assessment on the combination of the impact of landuse and climate change for 10-year ARI, Table 26 and Figures 120 to 125 show the assessment on the combination of the impact of landuse and climate change for 20-year ARI, Table 27 and Figures 126 to 131 show the assessment on the combination of the impact of landuse and climate change for 25-year ARI, Table 28 and Figures 132 to 137 show the assessment on the combination of the impact of landuse and climate change for 50-year

ARI and Table 29 and Figures 138 to 113 show the assessment on the combination of the impact of landuse and climate change for 100-year ARI.

Basically, the results show a significant increment in both water level and flow for various ARIs under the impact of both landuse change and climate change with increase of 0.932 m (8.451%) to 1.981 m (14.010%) for water level and increase of 2.434 m³/s (12.290%) to 109.474 m³/s (443.448%) for flow. For particular location at CH 425 (Weir Upstream), the results depicted a higher water level from 0.998 m (8.971%) to 1.921 m (15.641%) and higher flow from 34.565 m³/s (349.140%) to 109.474 m³/s (443.448%). At CH 425 (Weir Downstream), the results show an increment from 0.932 m (8.451 %) to 1.681 m (13.886%) in water level, while increment ranging from 2.434 m³/s (12.290%) to 17.709 m³/s (35.869%) for flow. The results also demonstrate an increment from 1.115 m (8.668%) to 1.981 m (14.010%) in water level, while increment from 24.788 m³/s (124.900%) to 84.826 m³/s (170.900%) at Sg Chini CH 4000 (Upstream of Sg Chini).

Table 25: Assessment on the combination of the impact of landuse and climate change for 10-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m/%)	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m ³ /s/%)
	10-year	10-year		10-year	10-year	
CH 425 (Weir Upstream)	11.125	12.123	+0.998 (8.971%)	9.900	44.465	+34.565 (349.141%)
CH 425 (Weir Downstream)	11.028	11.960	+0.932 (8.451%)	19.799	22.233	+2.434 (12.294%)
Sg Chini CH 4000 (Upstream of Sg Chini)	12.863	13.978	+1.115 (8.668%)	19.846	44.634	+24.788 (124.902%)

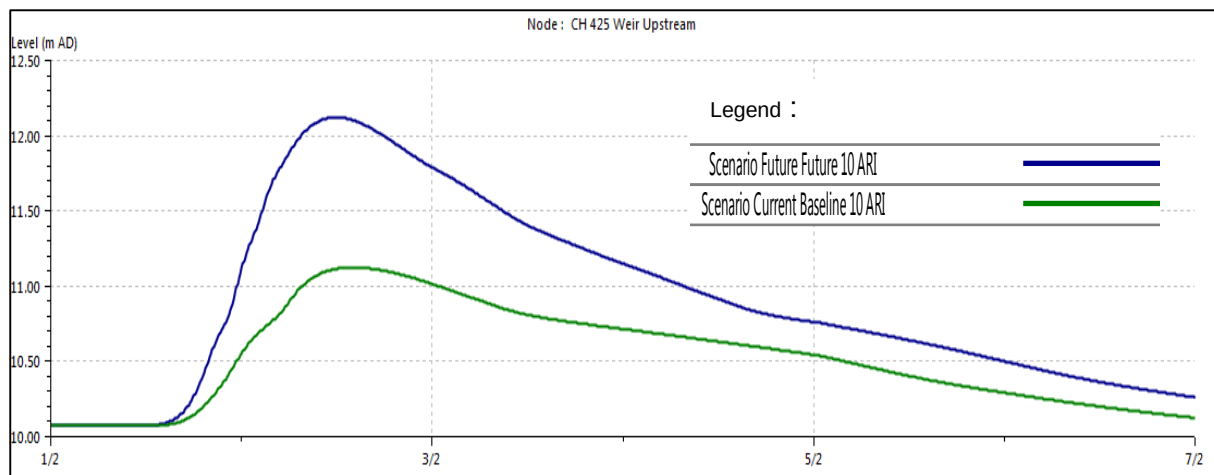


Figure 114: Comparison of water level on the combination of the impact of landuse and climate change for 10-year ARI at CH425 Weir Upstream

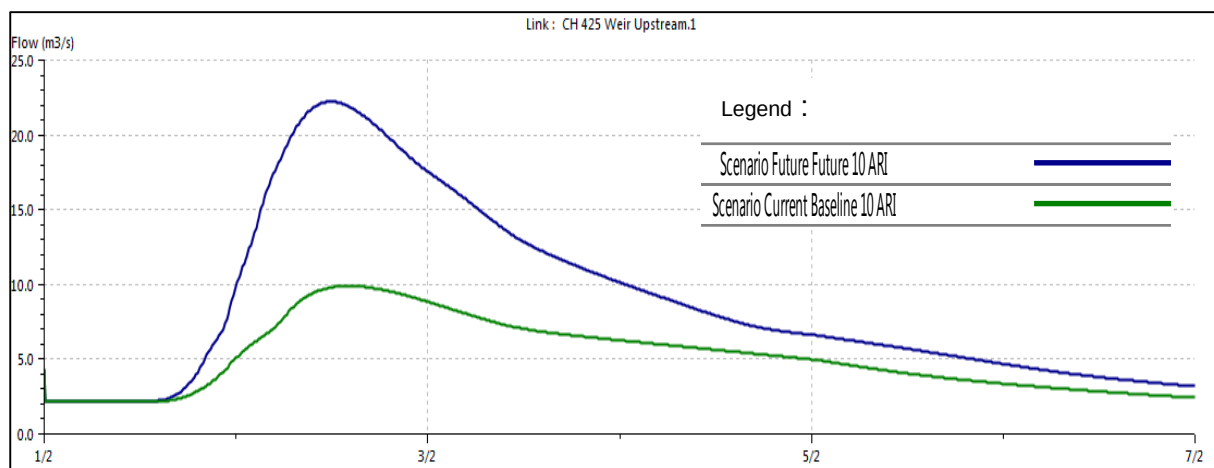


Figure 115: Comparison of flow on the combination of the impact of landuse and climate change for 10-year ARI at CH425 Weir Upstream

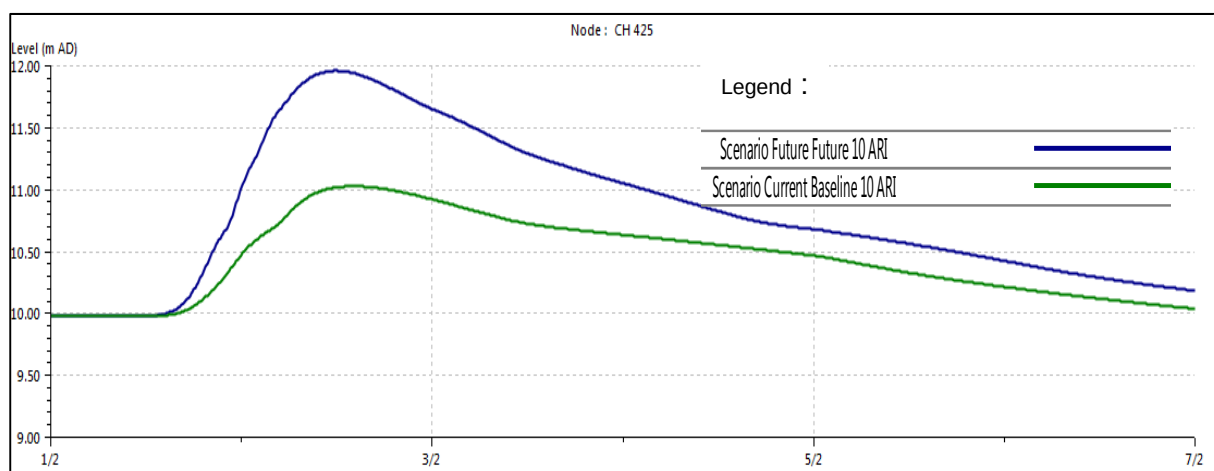


Figure 116: Comparison of water level on the combination of the impact of landuse and climate change for 10-year ARI at CH425 Weir Downstream

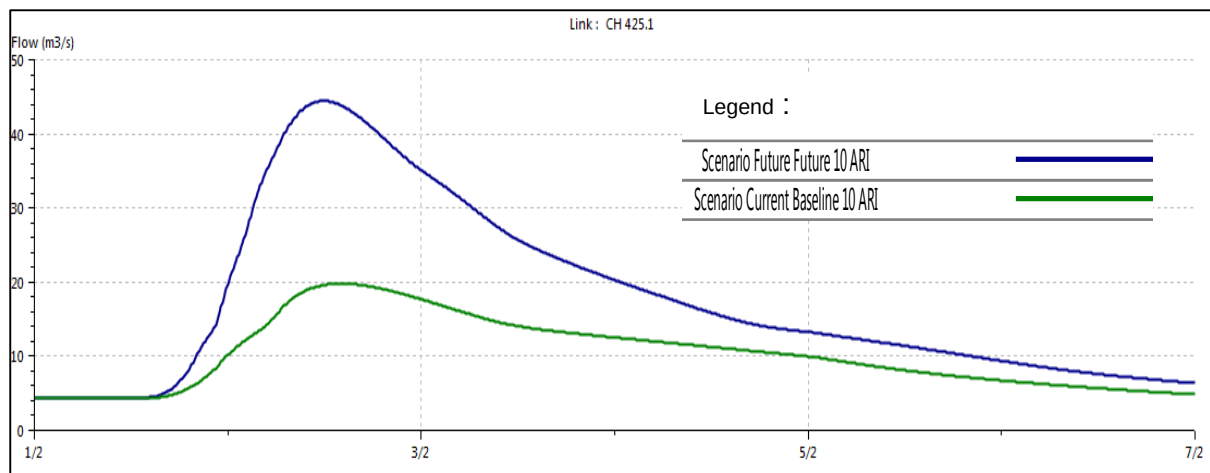


Figure 117: Comparison of flow on the combination of the impact of landuse and climate change for 10-year ARI at CH425 Weir Downstream

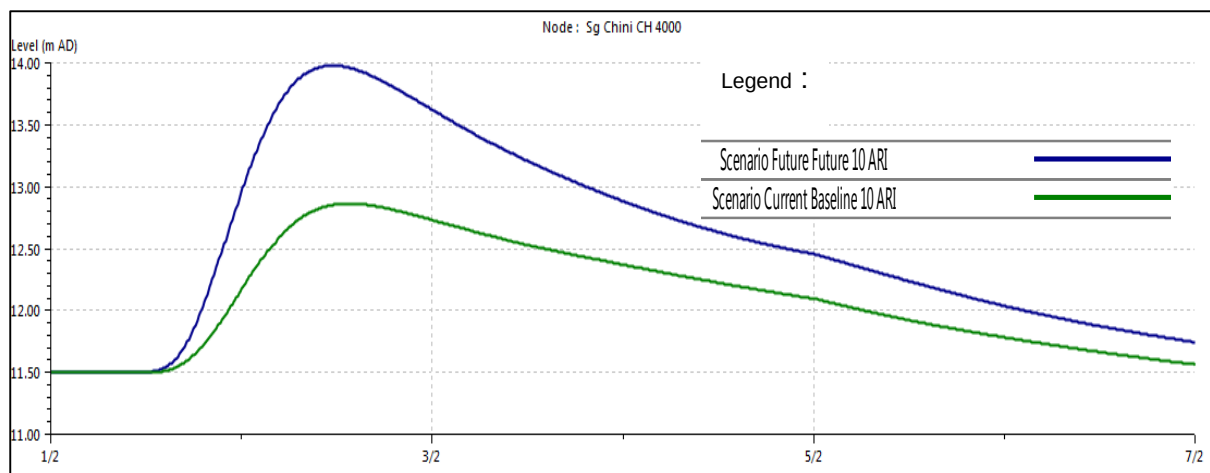


Figure 118: Comparison of water level on the combination of the impact of landuse and climate change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

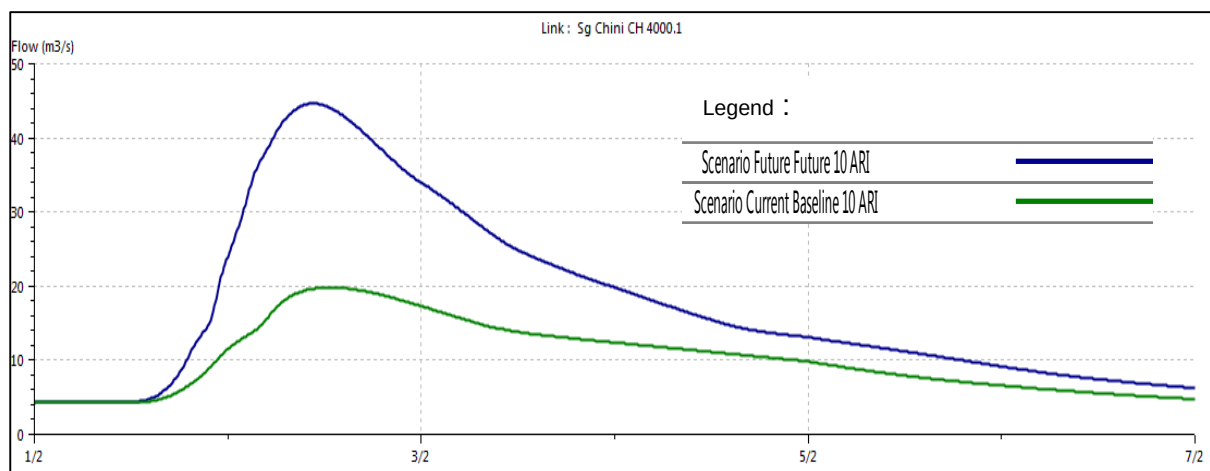


Figure 119: Comparison of flow on the combination of the impact of landuse and climate change for 10-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 26: Assessment on the combination of the impact of landuse and climate change for 20-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m/%)	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m ³ /s/%)
	20-year	20-year		20-year	20-year	
CH 425 (Weir Upstream)	11.386	12.661	+1.275 (11.198%)	12.641	63.657	+51.016 (403.576%)
CH 425 (Weir Downstream)	11.274	12.440	+1.166 (10.342%)	25.282	31.828	+6.546 (25.892%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.202	14.557	+1.355 (10.264%)	25.366	63.862	+38.496 (151.762%)

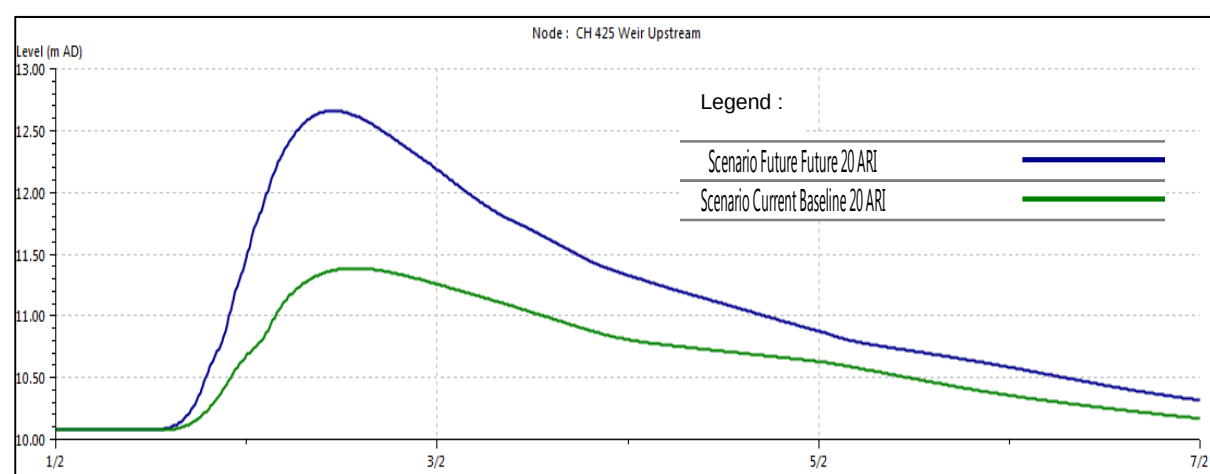


Figure 120: Comparison of water level on the combination of the impact of landuse and climate change for 20-year ARI at CH425 Weir Upstream

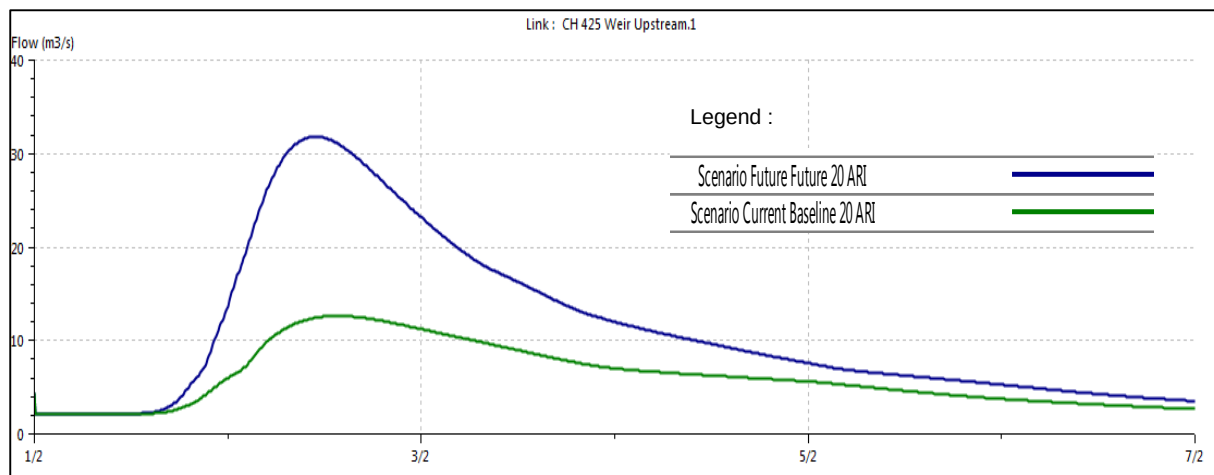


Figure 121: Comparison of flow on the combination of the impact of landuse and climate change for 20-year ARI at CH425 Weir Upstream

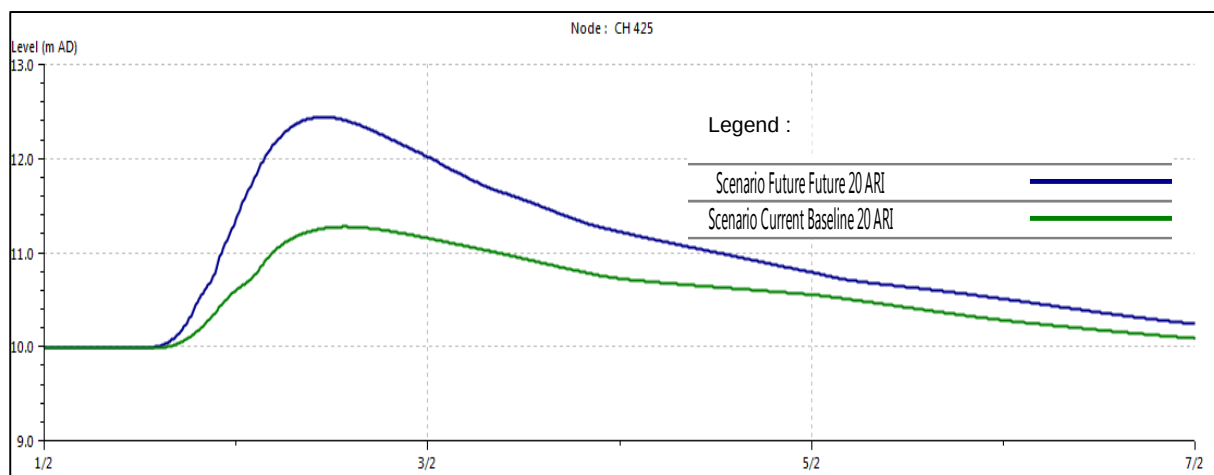


Figure 122: Comparison of water level on the combination of the impact of landuse and climate change for 20-year ARI at CH425 Weir Downstream

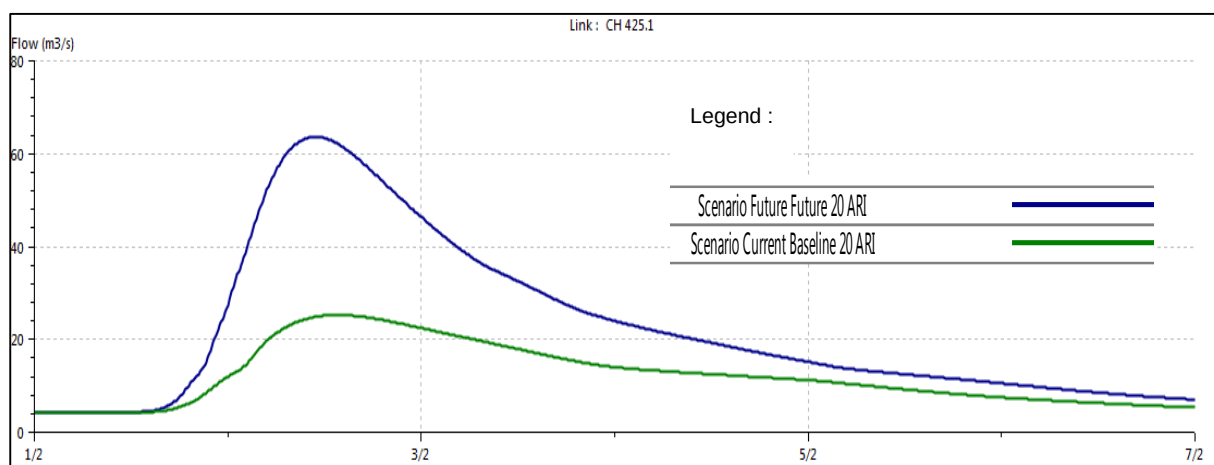


Figure 123: Comparison of flow on the combination of the impact of landuse and climate change for 20-year ARI at CH425 Weir Downstream

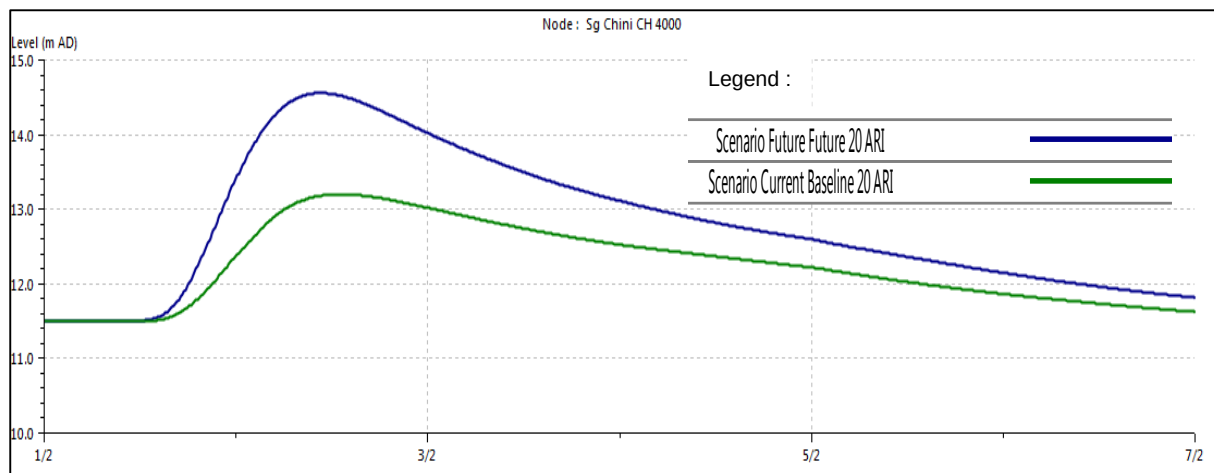


Figure 124: Comparison of water level on the combination of the impact of landuse and climate change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

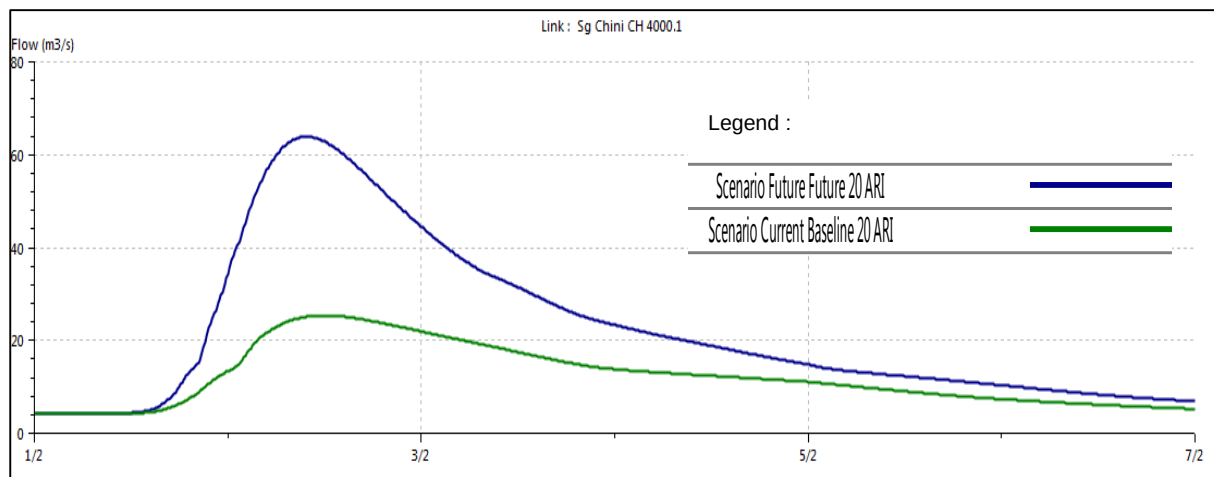


Figure 125: Comparison of flow on the combination of the impact of landuse and climate change for 20-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 27: Assessment on the combination of the impact of landuse and climate change for 25-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m/%)	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m ³ /s/%)
	25-year	25-year		25-year	25-year	
CH 425 (Weir Upstream)	11.497	12.936	+1.439 (12.516%)	13.926	74.777	+60.851 (436.960%)
CH 425 (Weir Downstream)	11.379	12.683	+1.304 (11.460%)	27.851	37.389	+9.538 (34.247%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.318	14.844	+1.526 (11.458%)	27.942	74.994	+47.052 (168.392%)

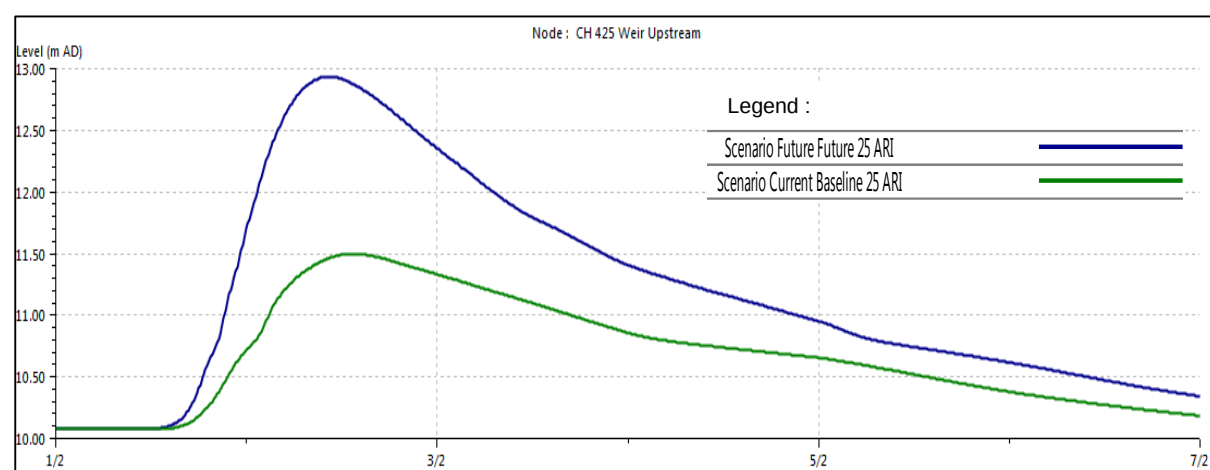


Figure 126: Comparison of water level on the combination of the impact of landuse and climate change for 25-year ARI at CH425 Weir Upstream

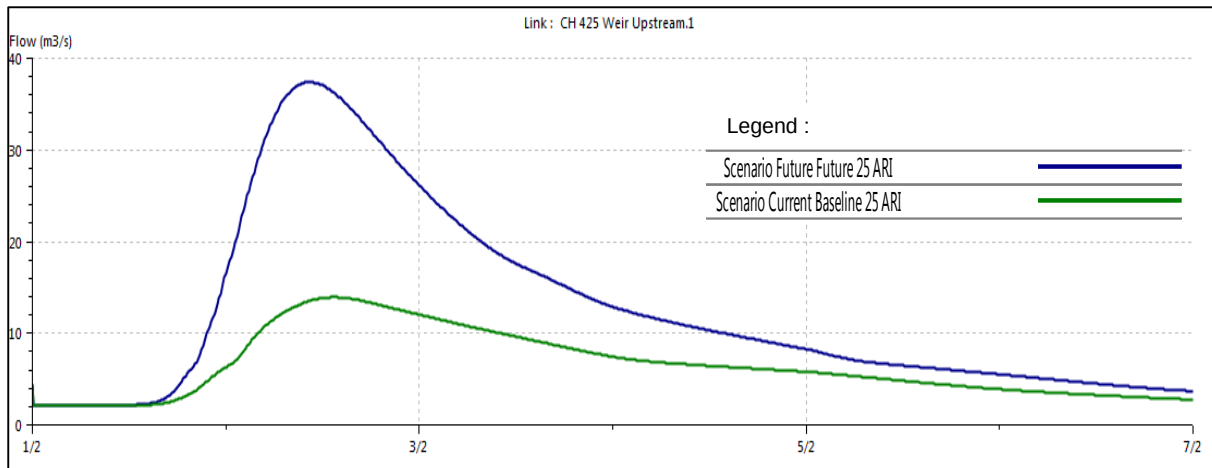


Figure 127: Comparison of flow on the combination of the impact of landuse and climate change for 25-year ARI at CH425 Weir Upstream

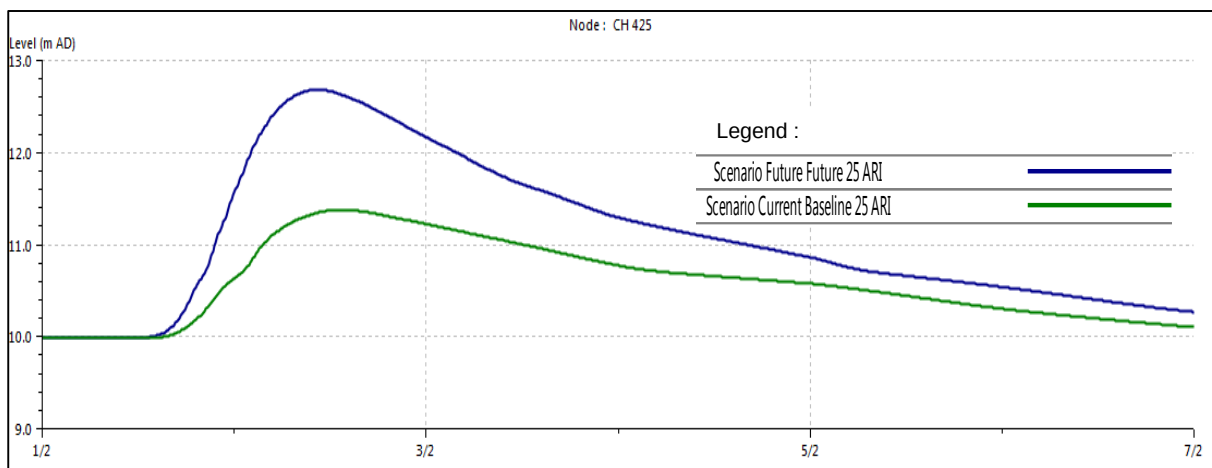


Figure 128: Comparison of water level on the combination of the impact of landuse and climate change for 25-year ARI at CH425 Weir Downstream

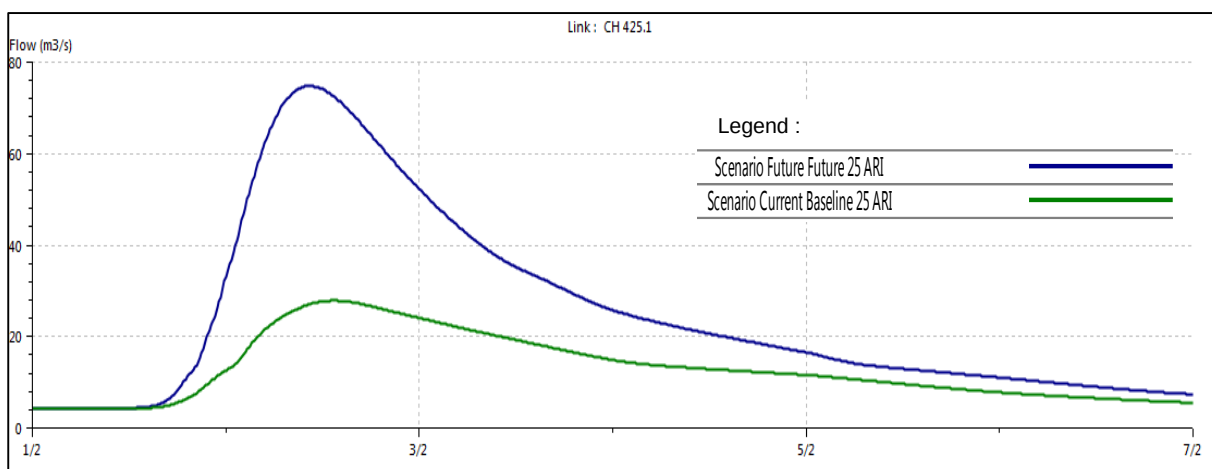


Figure 129: Comparison of flow on the combination of the impact of landuse and climate change for 25-year ARI at CH425 Weir Downstream

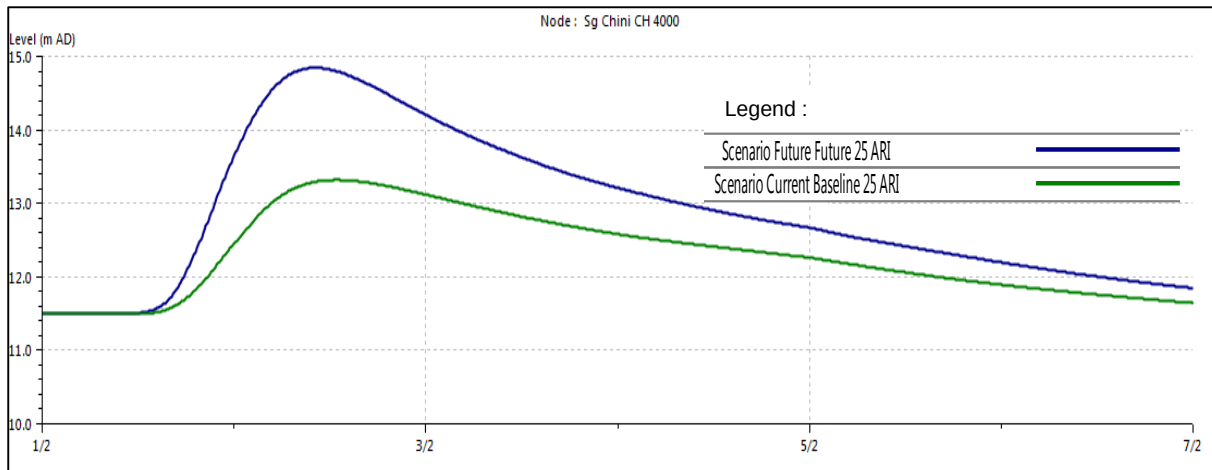


Figure 130: Comparison of water level on the combination of the impact of landuse and climate change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

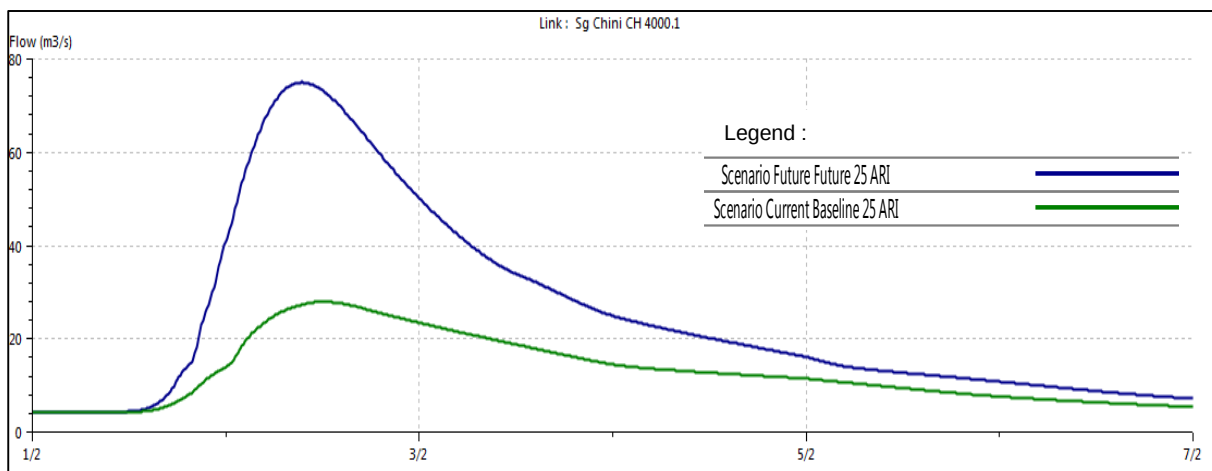


Figure 131: Comparison of flow on the combination of the impact of landuse and climate change for 25-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 28: Assessment on the combination of the impact of landuse and climate change for 50-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m/%)	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m ³ /s/%)
	50-year	50-year		50-year	50-year	
CH 425 (Weir Upstream)	11.846	13.645	+1.799 (15.187%)	18.306	104.720	+86.414 (472.053%)
CH 425 (Weir Downstream)	11.704	13.314	+1.610 (13.756%)	36.612	52.360	+15.748 (43.013%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.708	15.530	+1.822 (13.292%)	36.756	104.971	+68.215 (185.589%)

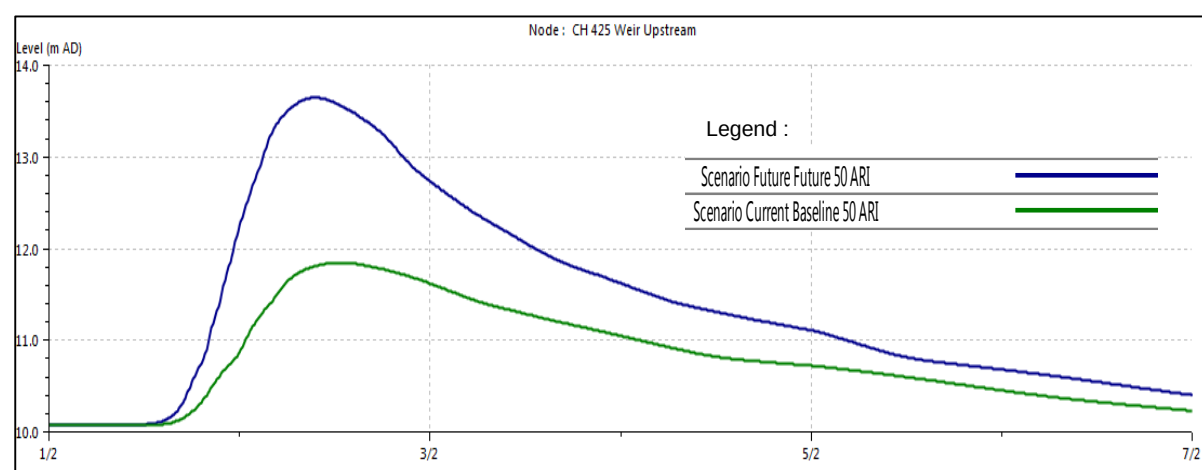


Figure 132: Comparison of water level on the combination of the impact of landuse and climate change for 50-year ARI at CH425 Weir Upstream

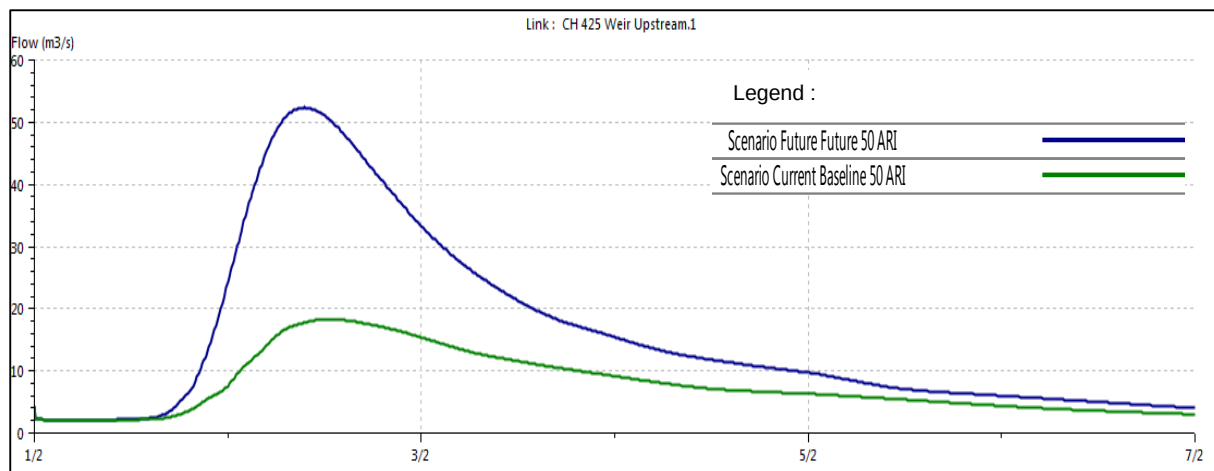


Figure 133: Comparison of flow on the combination of the impact of landuse and climate change for 50-year ARI at CH425 Weir Upstream

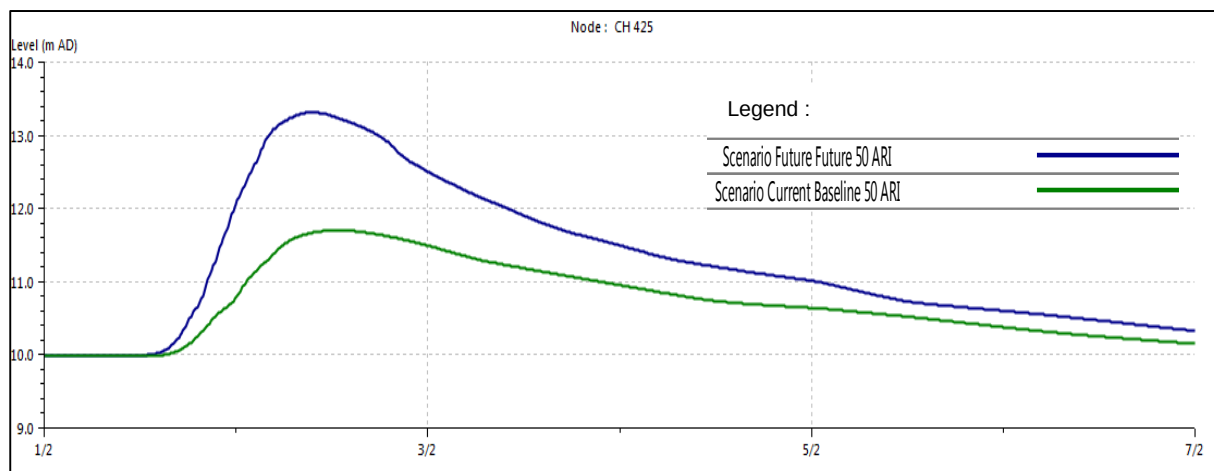


Figure 134: Comparison of water level on the combination of the impact of landuse and climate change for 50-year ARI at CH425 Weir Downstream

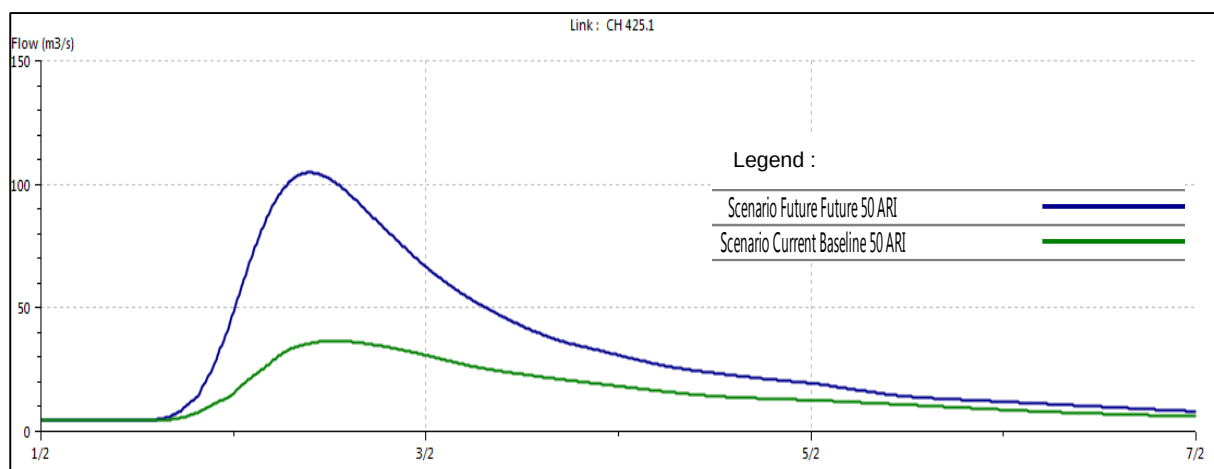


Figure 135: Comparison of flow on the combination of the impact of landuse and climate change for 50-year ARI at CH425 Weir Downstream

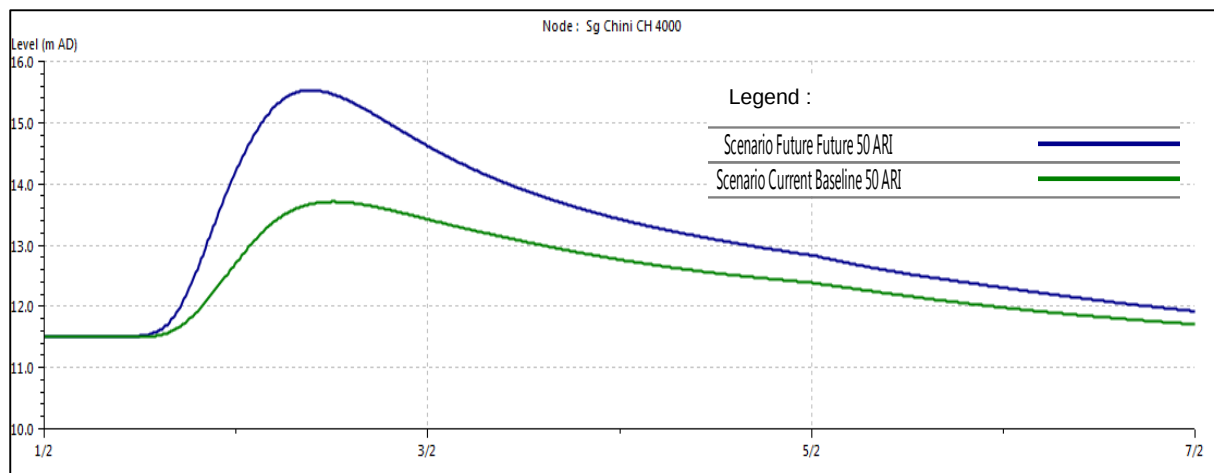


Figure 136: Comparison of water level on the combination of the impact of landuse and climate change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

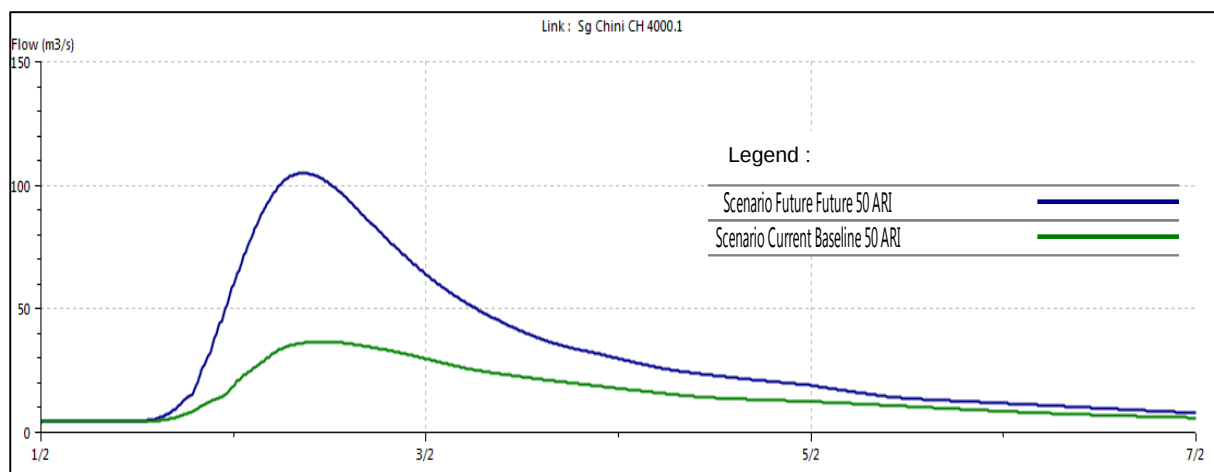


Figure 137: Comparison of flow on the combination of the impact of landuse and climate change for 50-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

Table 29: Assessment on the combination of the impact of landuse and climate change for 100-year ARI

ARI\ Node\Link	Maximum Water Level, metre			Maximum Flow, m ³ /s		
	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m/%)	Current Landuse and Baseline (Meteorology)	Future Landuse and Future (Meteorology)	Differences (m ³ /s/%)
	100-year	100-year		100-year	100-year	
CH 425 (Weir Upstream)	12.282	14.203	+1.921 (15.641%)	24.687	134.161	+109.474 (443.448%)
CH 425 (Weir Downstream)	12.106	13.787	+1.681 (13.886%)	49.372	67.081	+17.709 (35.869%)
Sg Chini CH 4000 (Upstream of Sg Chini)	14.137	16.118	+1.981 (14.013%)	49.636	134.462	+84.826 (170.896%)

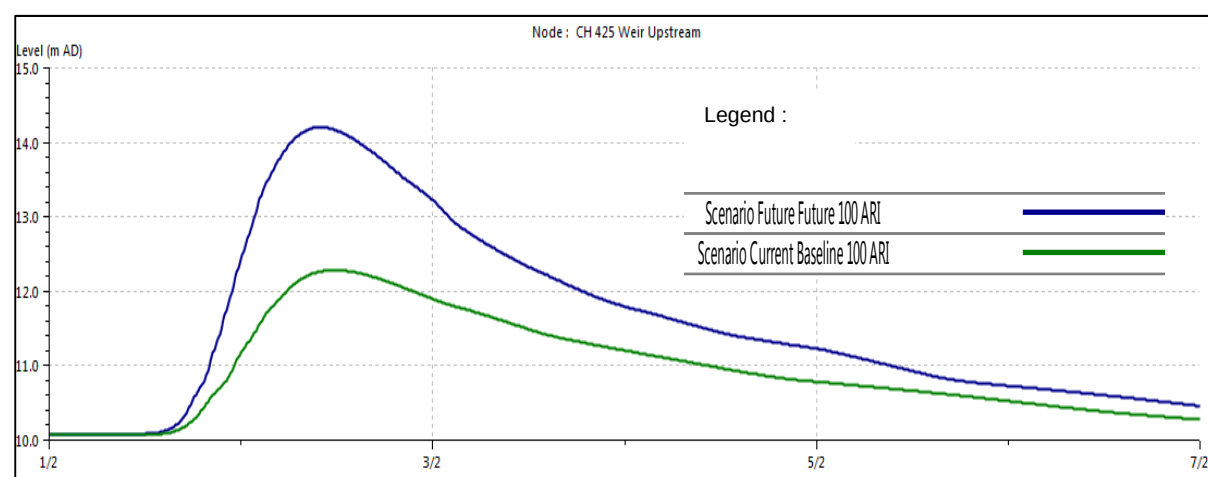


Figure 138: Comparison of water level on the combination of the impact of landuse and climate change for 100-year ARI at CH425 Weir Upstream

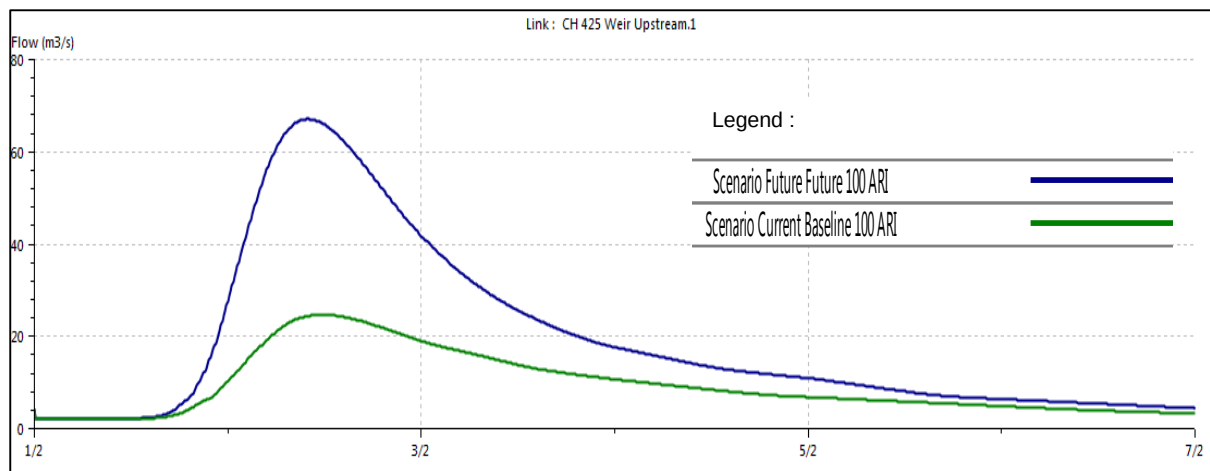


Figure 139: Comparison of flow on the combination of the impact of landuse and climate change for 100-year ARI at CH425 Weir Upstream

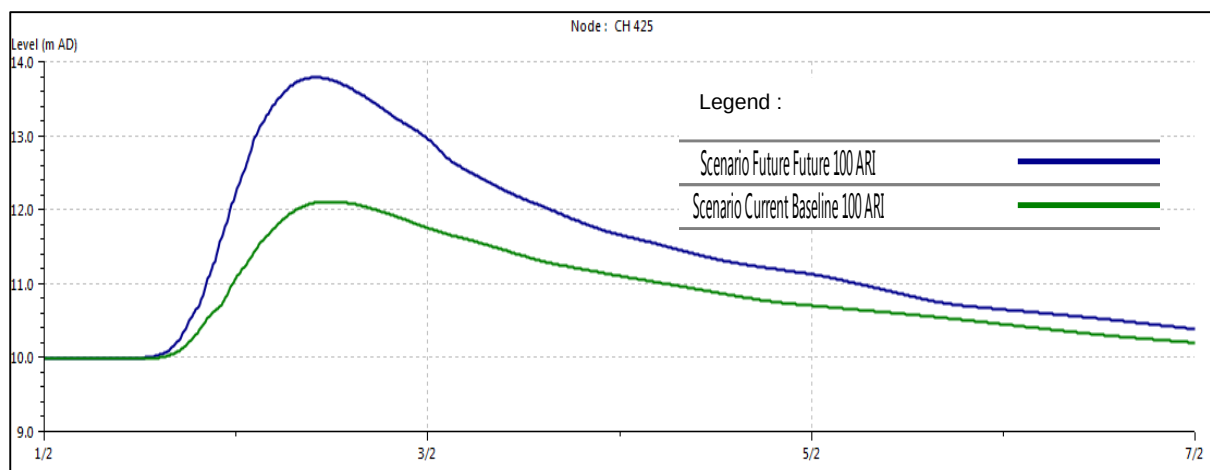


Figure 140: Comparison of water level on the combination of the impact of landuse and climate change for 100-year ARI at CH425 Weir Downstream

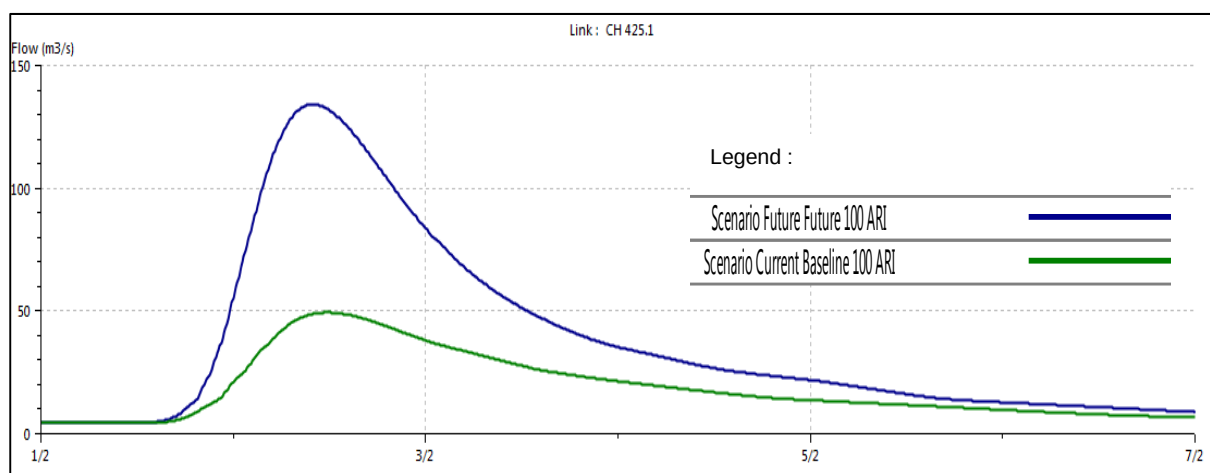


Figure 141: Comparison of flow on the combination of the impact of landuse and climate change for 100-year ARI at CH425 Weir Downstream

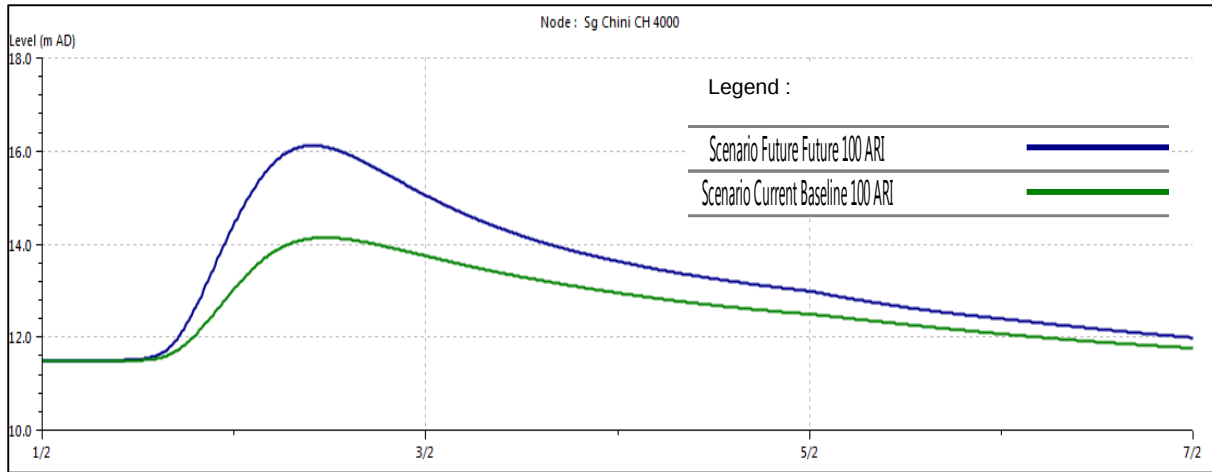


Figure 142: Comparison of water level on the combination of the impact of landuse and climate change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

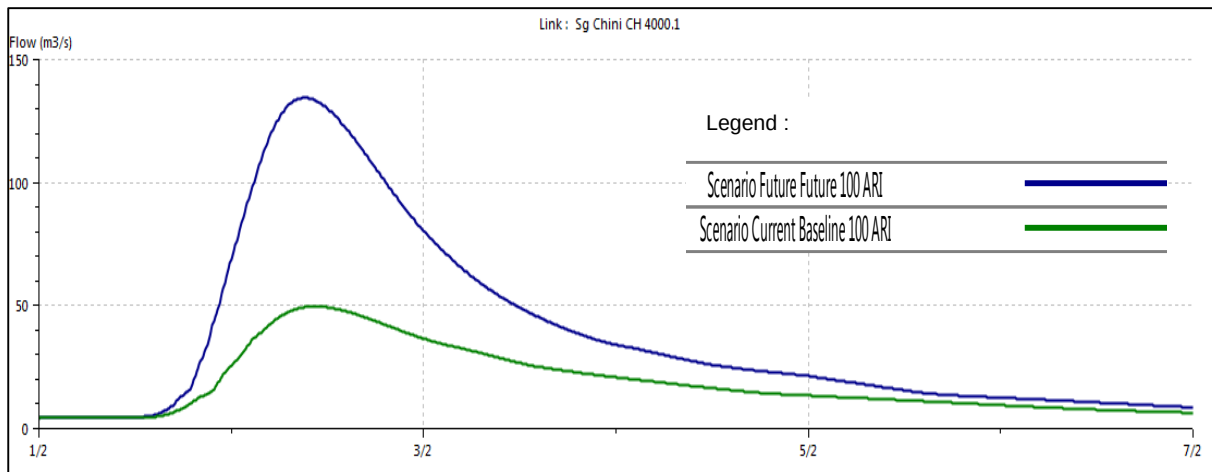


Figure 143: Comparison of flow on the combination of the impact of landuse and climate change for 100-year ARI at Sg Chini CH 4000 (Upstream of Sg Chini)

7.4 Assessment on the weir modification

An assessment was carried out to see the behaviour of flow in three different weir height, namely scenario with existing weir height (1.5m), scenario with decrease of 0.1m weir height (1.4m) and scenario with decrease of 0.25m weir height (1.25m) for existing landuse and climate, impact of landuse change, impact of climate change and also impact of both landuse change and climate change. Tables 30 to 37 and Figures 144 to 151 show the comparison of water level and flow for different weir height under various scenarios for 50-year ARI respectively, Tables 38 to 45 and Figures 152 to 159 show the comparison of water level and flow for different weir height under various scenarios for 100-year ARI respectively. For 50-year ARI the results show a decrease in water level at CH 425 upstream of weir from -0.011 to -0.013 m for weir height lowered with 0.1 m (weir height=1.4m) and from -0.082 to -0.126

m for weir height lowered with 0.25 m (weir height = 1.25 m). For flow, result shows increase in flow from 0.009 to 0.04 m³/s for weir height lowered with 0.1 m (weir height=1.4m) and from 0.056 to 0.235 m³/s for weir height lowered with 0.25 m (weir height = 1.25 m). For CH 425 weir downstream, results depicted a minimal increment of 0.001 m for weir height lowered with 0.1 m (weir height = 1.4 m) and from 0.004 to 0.008 m for weir height lowered with 0.25 m (weir height = 1.25 m). For flow, results demonstrate increase in flow from 0.018 to 0.052 m³/s for weir height lowered with 0.1 m (weir height=1.4m) and from 0.111 to 0.47 m³/s for weir height lowered with 0.25 m (weir height = 1.25 m). While, at Sg Chini CH 4000 Upstream of Sg Chini, the water level show decrease in water level for 0.001 m for weir height lowered with 0.1 m (weir height=1.4m) and decrease in -0.002 to -0.006 m for weir height lowered with 0.25 m (weir height = 1.25 m). For flow, results demonstrate increase in flow from 0.017 to 0.052 m³/s for weir height lowered with 0.1 m (weir height=1.4m) and from 0.104 to 0.465 m³/s for weir height lowered with 0.25 m (weir height = 1.25 m).

For 100-year ARI the results show a decrease in water level at CH 425 upstream of weir from -0.011 to -0.019 m for weir height lowered with 0.1 m (weir height=1.4m) and from -0.093 to -0.139 m for weir height lowered with 0.25 m (weir height = 1.25 m). For flow, result shows increase in flow from 0.014 to 0.049 m³/s for weir height lowered with 0.1 m (weir height=1.4m) and from 0.112 to 0.394 m³/s for weir height lowered with 0.25 m (weir height = 1.25 m). For CH 425 weir downstream, results depicted a minimal increment of 0.001 to 0.002 m for weir height lowered with 0.1m (weir height = 1.4 m) and from 0.006 to 0.013 m for weir height lowered with 0.25 m (weir height = 1.25 m). For flow, results demonstrate increase in flow from 0.027 to 0.100 m³/s for weir height lowered with 0.1 m (weir height=1.4m) and from 0.223 to 0.790 m³/s for weir height lowered with 0.25 m (weir height = 1.25 m). While, at Sg Chini CH 4000 Upstream of Sg Chini, the water level show decrease in water level for -0.001 m for weir height lowered with 0.1 m (weir height=1.4m) and decrease in -0.003 to -0.009 m for weir height lowered with 0.25 m (weir height = 1.25 m). For flow, results demonstrate increase in flow from 0.024 to 0.083 m³/s for weir height lowered with 0.1 m (weir height=1.4m) and from 0.209 to 0.777 m³/s for weir height lowered with 0.25 m (weir height = 1.25 m).

Table 30: Assessment of the water level changes for different weir's height for Current Landuse and Baseline (Meteorology) for 50-year ARI

ARI\ Node\Link	Maximum Water Level, metre				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m/%)	Weir Height: 1.25 m	Differences (m/%)
	50-year	50-year		50-year	
CH 425 (Weir Upstream)	11.846	11.835	-0.011 (0.093%)	11.764	-0.082 (0.692%)
CH 425 (Weir Downstream)	11.704	11.705	+0.001 (0.009%)	11.708	+0.004 (0.034%)
Sg Chini CH 4000 (Upstream of Sg Chini)	13.708	13.707	-0.001 (0.007%)	13.706	-0.002 (0.015%)

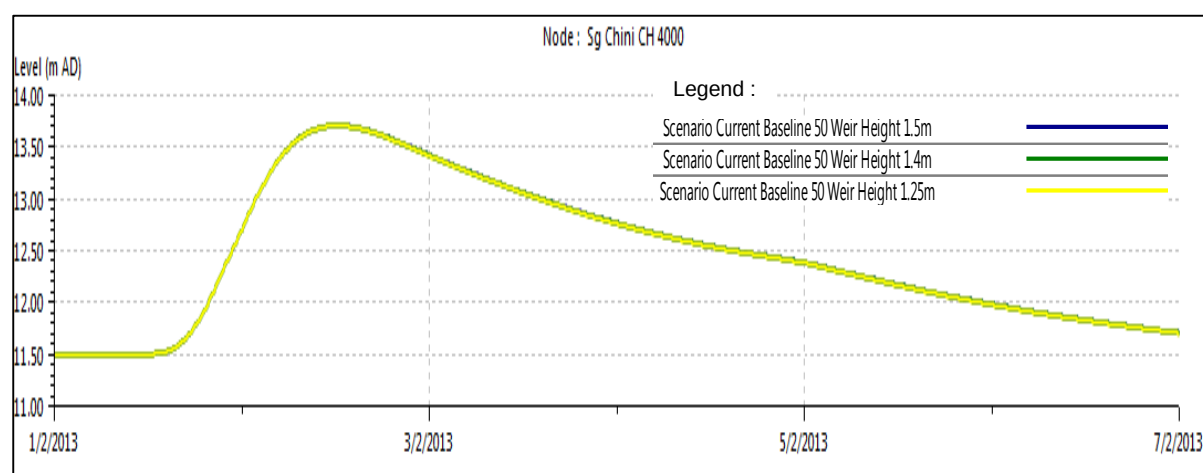


Figure 144: Comparison of water level for different weir's height for Current Landuse and Baseline (Meteorology) for 50-year ARI

Table 31: Assessment of the flow changes for different weir's height for Current Landuse and Baseline (Meteorology) for 50-year ARI

ARI\ Node\Link	Maximum Flow, m ³ /s				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m ³ /s/%)	Weir Height: 1.25 m	Differences (m/%)
	50-year	50-year		50-year	
CH 425 (Weir Upstream)	18.306	18.315	0.009 (0.049%)	18.362	0.056 (0.306%)
CH 425 (Weir Downstream)	36.612	36.63	0.018 (0.049%)	36.723	0.111 (0.303%)
Sg Chini CH 4000 (Upstream of Sg Chini)	36.756	36.774	0.018 (0.049%)	36.86	0.104 (0.283%)

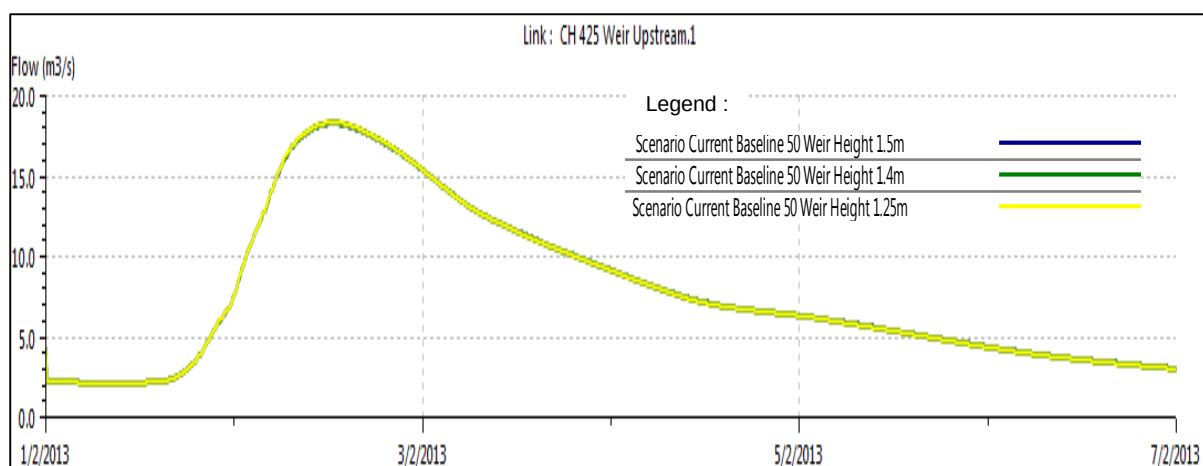


Figure 145: Comparison of flow for different weir's height for Current Landuse and Baseline (Meteorology) for 50-year ARI

Table 32: Assessment of the water level changes for different weir's height for Current Landuse and Future (Meteorology) for 50-year ARI

ARI\ Node\Link	Maximum Water Level, metre				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m/%)	Weir Height: 1.25 m	Differences (m/%)
	50-year	50-year		50-year	
CH 425 (Weir Upstream)	13.546	13.553	0.007 (0.052%)	13.422	-0.124 (0.915%)
CH 425 (Weir Downstream)	13.228	13.229	0.001 (0.008%)	13.235	0.007 (0.053%)
Sg Chini CH 4000 (Upstream of Sg Chini)	15.430	15.43	0 (0%)	15.424	-0.006 (0.039%)

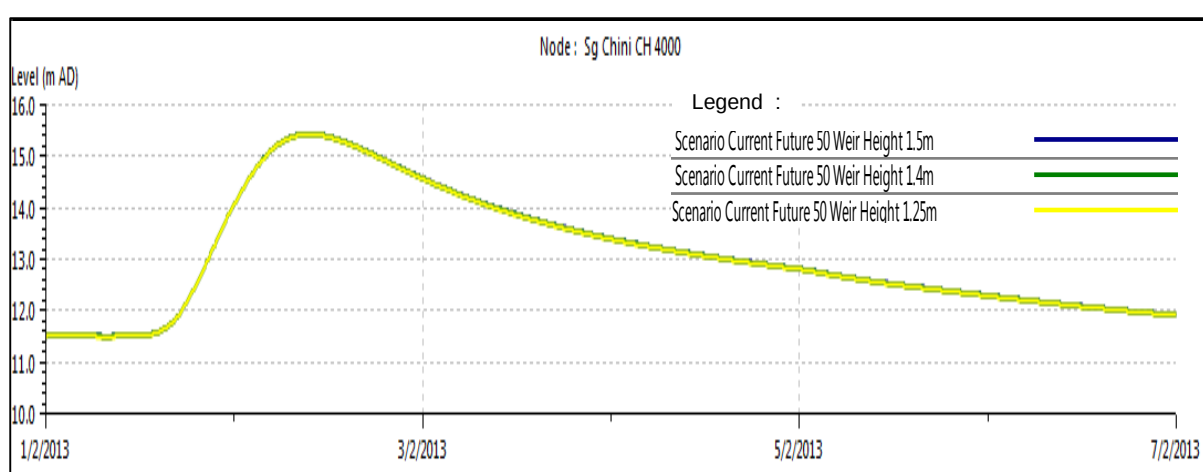


Figure 146: Comparison of water level for different weir's height for Current Landuse and Future (Meteorology) for 50-year ARI

Table 33: Assessment of the flow changes for different weir's height for Current Landuse and Future (Meteorology) for 50-year ARI

ARI\ Node\Link	Maximum Flow, m ³ /s				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m ³ /s/%)	Weir Height: 1.25 m	Differences (m/%)
	50-year	50-year		50-year	
CH 425 (Weir Upstream)	50.030	50.07	0.04 (0.08%)	50.233	0.203 (0.406%)
CH 425 (Weir Downstream)	100.060	100.14	0.08 (0.08%)	100.466	0.406 (0.406%)
Sg Chini CH 4000 (Upstream of Sg Chini)	100.251	100.299	0.048 (0.048%)	100.683	0.432 (0.431%)

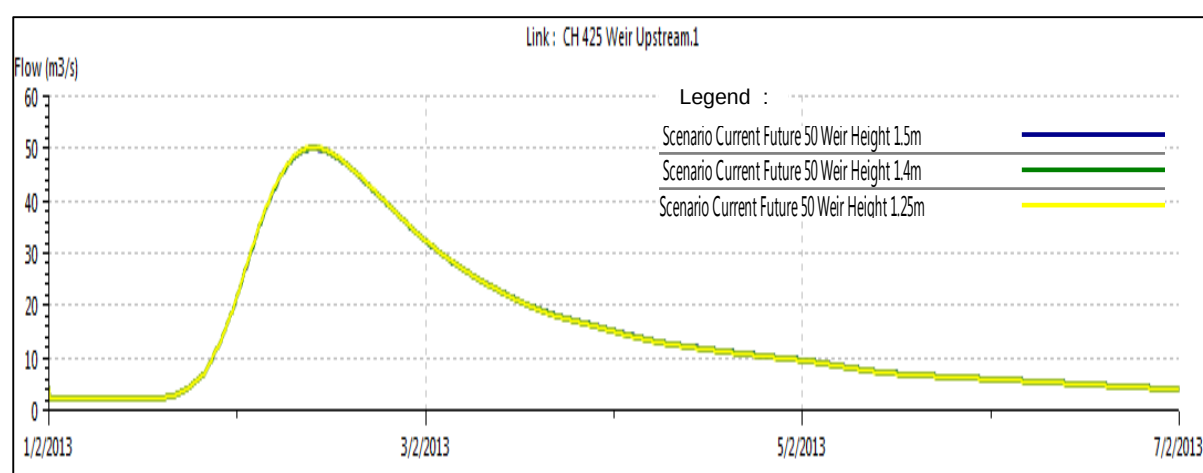


Figure 147: Comparison of flow for different weir's height for Current Landuse and Future (Meteorology) for 50-year ARI

Table 34: Assessment of the water level changes for different weir's height for Future Landuse and Baseline (Meteorology) for 50-year ARI

ARI\ Node\Link	Maximum Water Level, metre				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m/%)	Weir Height: 1.25 m	Differences (m/%)
	50-year	50-year		50-year	
CH 425 (Weir Upstream)	11.930	11.919	-0.011 (0.092%)	11.847	-0.083 (0.696%)
CH 425 (Weir Downstream)	11.782	11.783	0.001 (0.008%)	11.787	0.005 (0.042%)
Sg Chini CH 4000 (Upstream of Sg Chini)	11.793	11.793	0 (0 %)	11.791	-0.002 (0.017%)

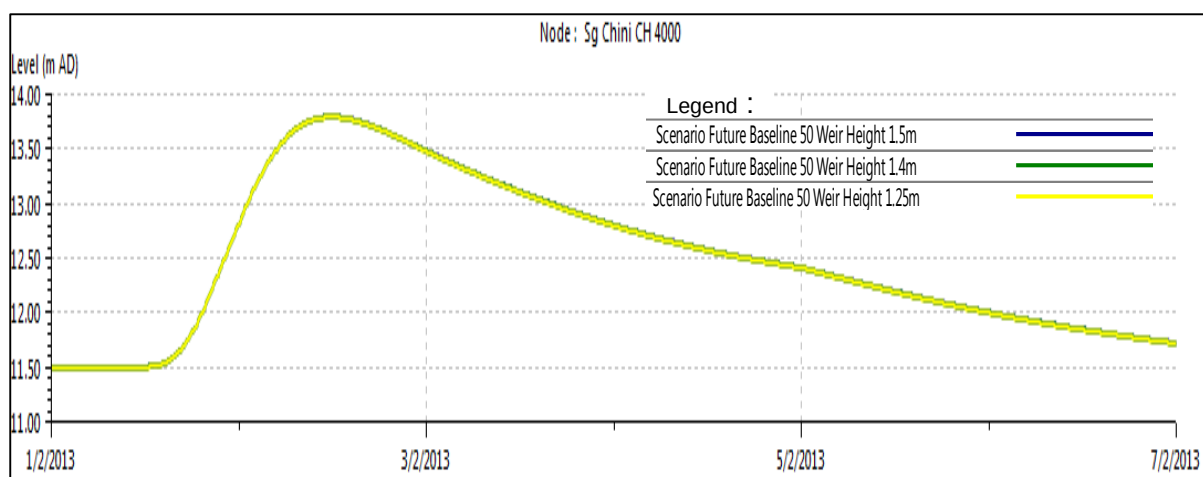


Figure 148: Comparison of water level for different weir's height for Future Landuse and Baseline (Meteorology) for 50-year ARI

Table 35: Assessment of the flow changes for different weir's height for Future Landuse and Baseline (Meteorology) for 50-year ARI

ARI\ Node\Link	Maximum Flow, m ³ /s				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m ³ /s/%)	Weir Height: 1.25 m	Differences (m/%)
	50-year	50-year		50-year	
CH 425 (Weir Upstream)	19.456	19.465	0.009 (0.046%)	19.521	0.065 (0.334%)
CH 425 (Weir Downstream)	38.911	38.929	0.018 (0.046%)	39.042	0.131 (0.337%)
Sg Chini CH 4000 (Upstream of Sg Chini)	39.062	39.079	0.017 (0.044%)	39.185	0.123 (0.315%)

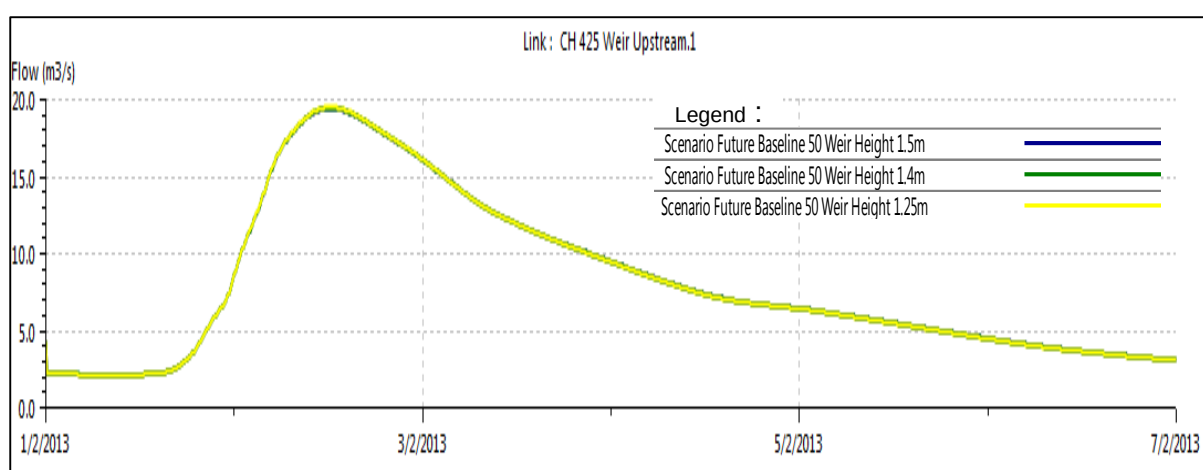


Figure 149: Comparison of flow for different weir's height for Future Landuse and Baseline (Meteorology) for 50-year ARI

Table 36: Assessment of the water level changes for different weir's height for Future Landuse and Future (Meteorology) for 50-year ARI

ARI\ Node\Link	Maximum Water Level, metre				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m/%)	Weir Height: 1.25 m	Differences (m/%)
	50-year	50-year		50-year	
CH 425 (Weir Upstream)	13.645	13.632	-0.013 (0.095%)	13.519	-0.126 (0.923%)
CH 425 (Weir Downstream)	13.314	13.315	0.001 (0.008%)	13.322	0.008 (0.06%)
Sg Chini CH 4000 (Upstream of Sg Chini)	15.530	15.53	0 (0%)	15.524	-0.006 (0.039%)

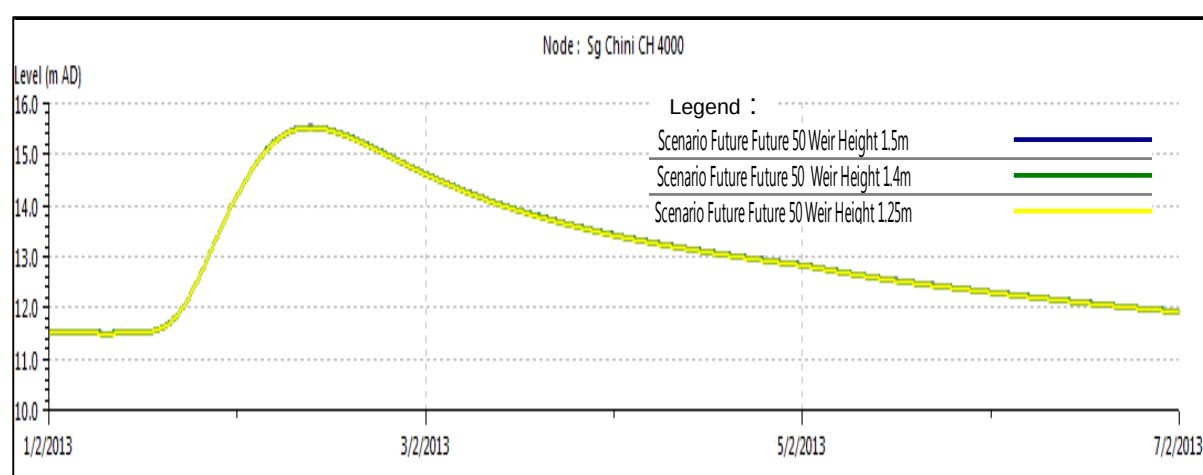


Figure 150: Comparison of water level for different weir's height for Future Landuse and Future (Meteorology) for 50-year ARI

Table 37: Assessment of the flow changes for different weir's height for Future Landuse and Future (Meteorology) for 50-year ARI

ARI\ Node\Link	Maximum Flow, m ³ /s				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m ³ /s/%)	Weir Height: 1.25 m	Differences (m/%)
	50-year	50-year		50-year	
CH 425 (Weir Upstream)	52.360	52.386	0.026 (0.05%)	52.595	0.235 (0.449%)
CH 425 (Weir Downstream)	104.720	104.772	0.052 (0.05%)	105.190	0.47 (0.449%)
Sg Chini CH 4000 (Upstream of Sg Chini)	104.971	105.023	0.052 (0.05%)	105.436	0.465 (0.443%)

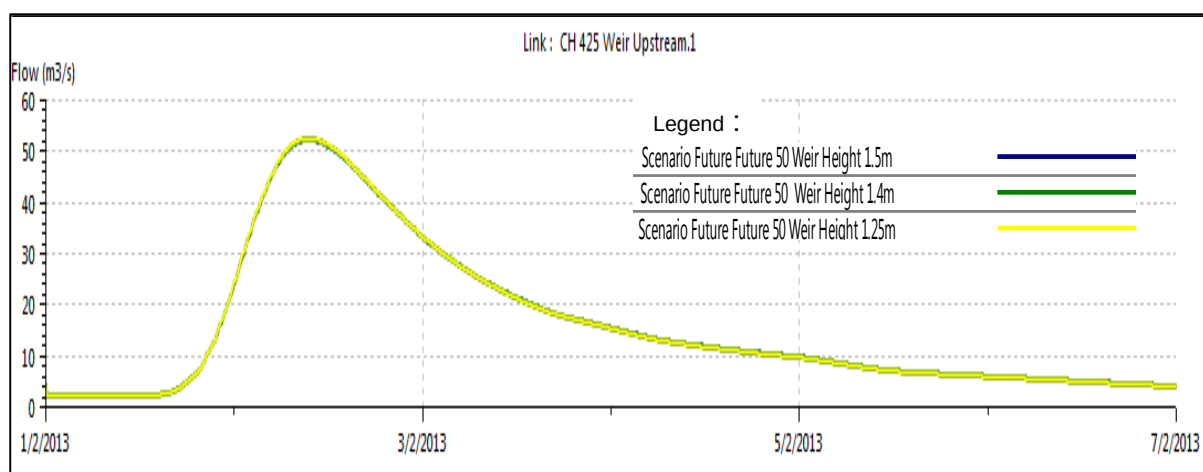


Figure 151: Comparison of flow for different weir's height for Future Landuse and Future (Meteorology) for 50-year ARI

Table 38: Assessment of the water level changes for different weir's height for Current Landuse and Baseline (Meteorology) for 100-year ARI

ARI\ Node\Link	Maximum Water Level, metre				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m/%)	Weir Height: 1.25 m	Differences (m/%)
	100-year	100-year		100-year	
CH 425 (Weir Upstream)	12.282	12.263	-0.019 (0.155%)	12.183	-0.099 (0.806%)
CH 425 (Weir Downstream)	12.106	12.097	-0.009 (0.074%)	12.102	-0.004 (0.033%)
Sg Chini CH 4000 (Upstream of Sg Chini)	14.137	14.137	0 (0%)	14.135	-0.002 (0.014%)

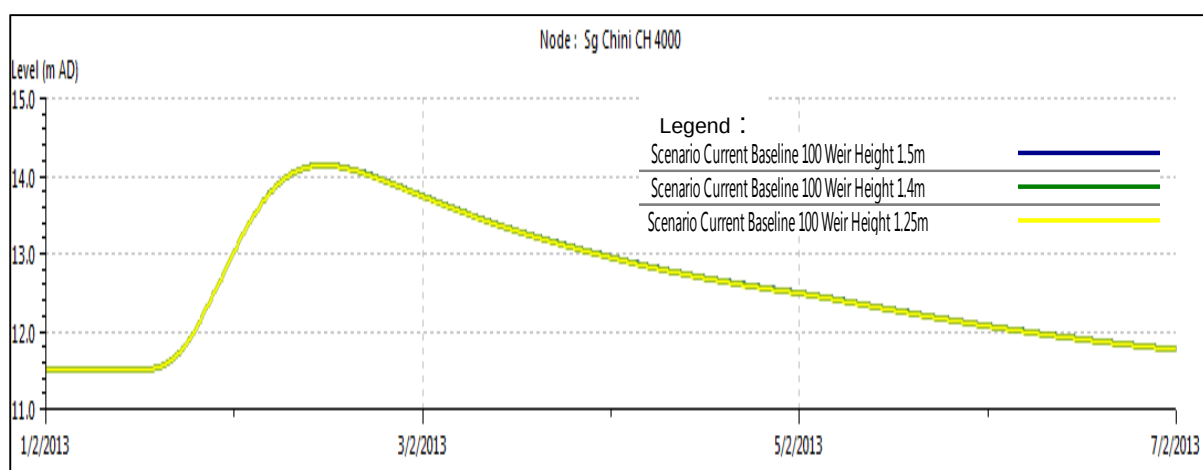


Figure 152: Comparison of water level for different weir's height for Current Landuse and Baseline (Meteorology) for 100-year ARI

Table 39: Assessment of the flow changes for different weir's height for Current Landuse and Baseline (Meteorology) for 100-year ARI

ARI\ Node\Link	Maximum Flow, m ³ /s				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m ³ /s/%)	Weir Height: 1.25 m	Differences (m/%)
	100-year	100-year		100-year	
CH 425 (Weir Upstream)	24.687	24.736	0.049 (0.198%)	24.830	0.143 (0.579%)
CH 425 (Weir Downstream)	49.372	49.472	0.1 (0.203%)	49.661	0.289 (0.585%)
Sg Chini CH 4000 (Upstream of Sg Chini)	49.636	49.660	0.024 (0.048%)	49.845	0.209 (0.421%)

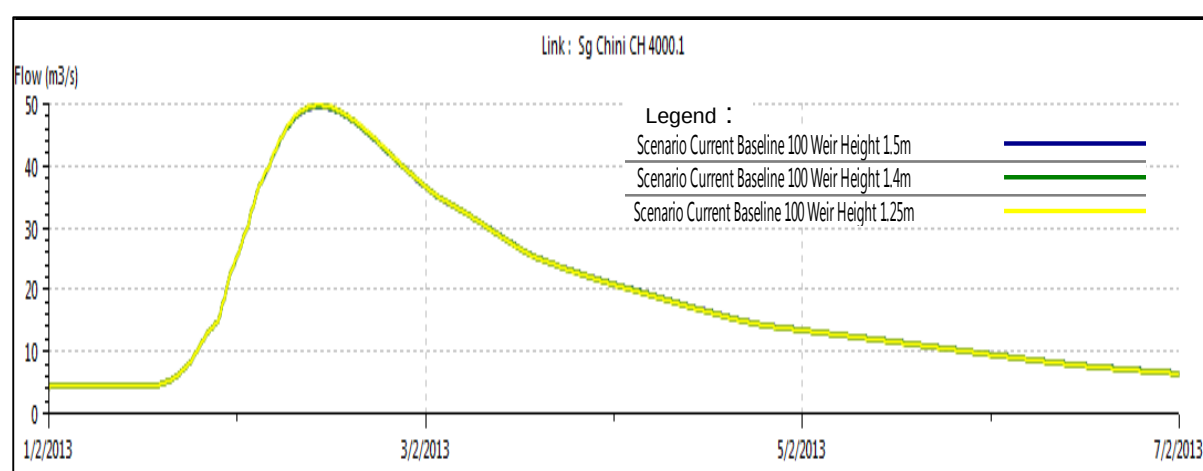


Figure 153: Comparison of flow for different weir's height for Current Landuse and Baseline (Meteorology) for 100-year ARI

Table 40: Assessment of the water level changes for different weir's height for Current Landuse and Future (Meteorology) for 100-year ARI

ARI\ Node\Link	Maximum Water Level, metre				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m/%)	Weir Height: 1.25 m	Differences (m/%)
	100-year	100-year		100-year	
CH 425 (Weir Upstream)	14.128	14.114	-0.014 (0.099%)	13.990	-0.138 (0.977%)
CH 425 (Weir Downstream)	13.723	13.724	0.001 (0.007%)	13.735	0.012 (0.087%)
Sg Chini CH 4000 (Upstream of Sg Chini)	16.040	16.039	-0.001 (0.006%)	16.031	-0.009 (0.056%)

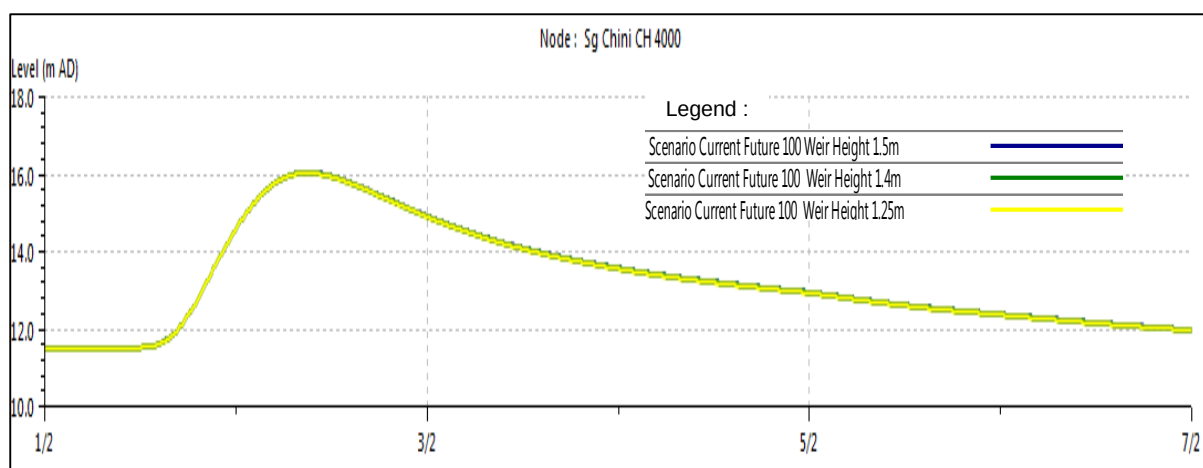


Figure 154: Comparison of water level for different weir's height for Current Landuse and Future (Meteorology) for 100-year ARI

Table 41: Assessment of the flow changes for different weir's height for Current Landuse and Future (Meteorology) for 100-year ARI

ARI\ Node\Link	Maximum Flow, m ³ /s				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m ³ /s/%)	Weir Height: 1.25 m	Differences (m/%)
	100-year	100-year		100-year	
CH 425 (Weir Upstream)	65.043	65.083	0.04 (0.061%)	65.419	0.376 (0.578%)
CH 425 (Weir Downstream)	130.086	130.166	0.08 (0.061%)	130.838	0.752 (0.578%)
Sg Chini CH 4000 (Upstream of Sg Chini)	130.391	130.470	0.079 (0.061%)	131.130	0.739 (0.567%)

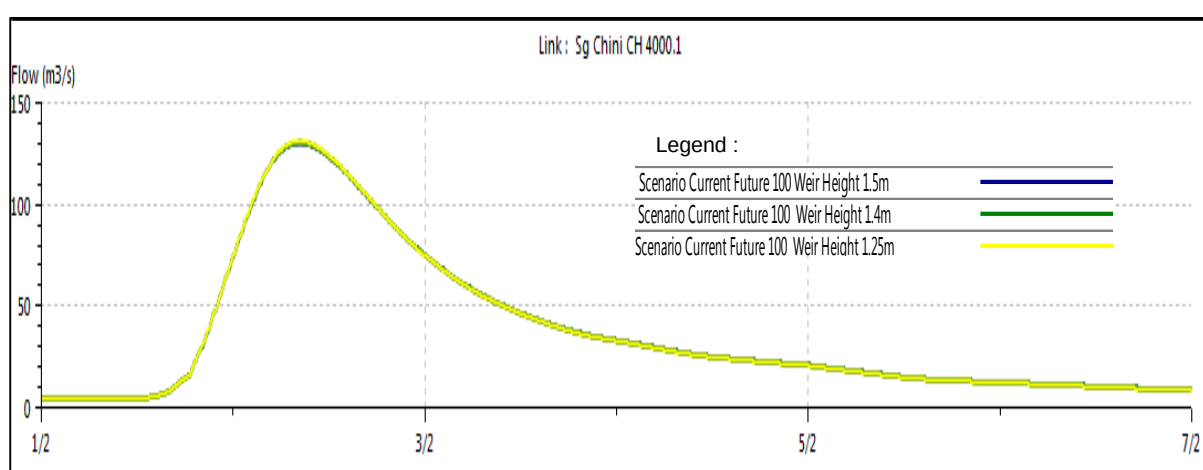


Figure 155: Comparison of flow for different weir's height for Current Landuse and Future (Meteorology) for 100-year ARI

Table 42: Assessment of the water level changes for different weir's height for Future Landuse and Baseline (Meteorology) for 100-year ARI

ARI\ Node\Link	Maximum Water Level, metre				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m/%)	Weir Height: 1.25 m	Differences (m/%)
	100-year	100-year		100-year	
CH 425 (Weir Upstream)	12.354	12.343	-0.011 (0.089%)	12.261	-0.093 (0.753%)
CH 425 (Weir Downstream)	12.168	12.169	0.001 (0.008%)	12.174	0.006 (0.049%)
Sg Chini CH 4000 (Upstream of Sg Chini)	14.227	14.227	0 (0%)	14.224	-0.003 (0.021%)

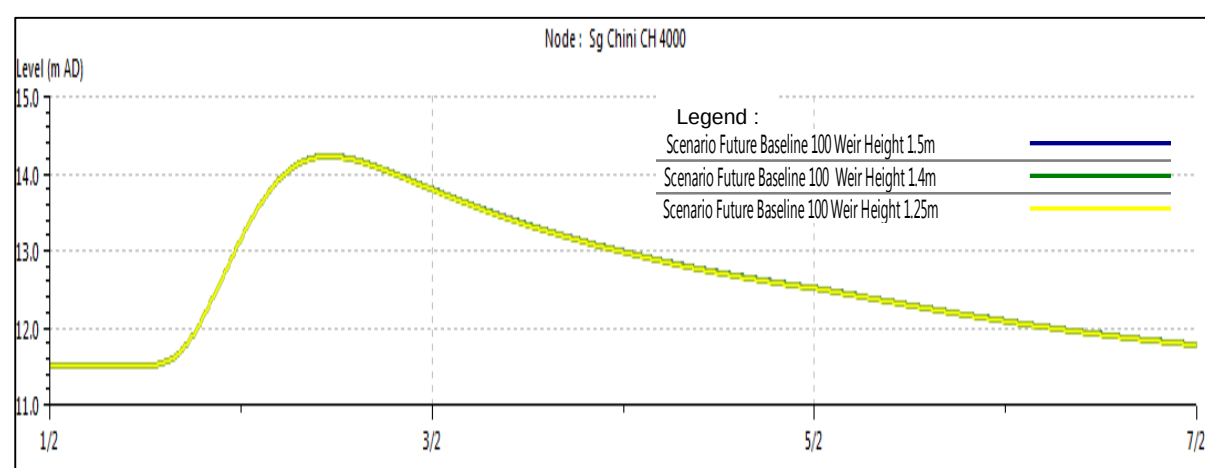


Figure 156: Comparison of water level for different weir's height for Future Landuse and Baseline (Meteorology) for 100-year ARI

Table 43: Assessment of the flow changes for different weir's height for Future Landuse and Baseline (Meteorology) for 100-year ARI

ARI\ Node\Link	Maximum Flow, m ³ /s				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m ³ /s/%)	Weir Height: 1.25 m	Differences (m/%)
	100-year	100-year		100-year	
CH 425 (Weir Upstream)	26.150	26.164	0.014 (0.054%)	26.262	+0.112 (0.428%)
CH 425 (Weir Downstream)	52.301	52.328	0.027 (0.052%)	52.524	+0.223 (0.426%)
Sg Chini CH 4000 (Upstream of Sg Chini)	52.492	52.519	0.027 (0.051%)	52.712	+0.220 (0.419%)

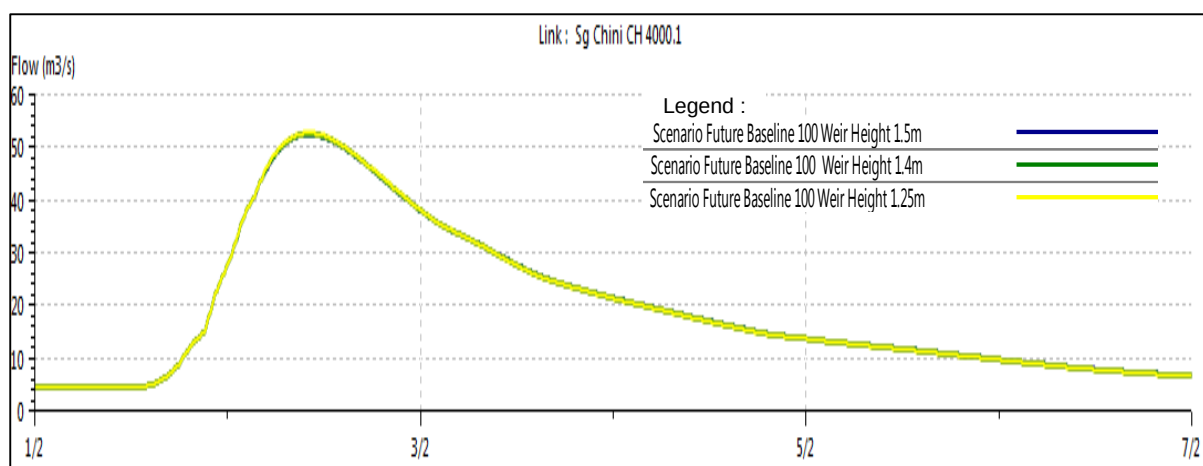


Figure 157: Comparison of flow for different weir's height for Future Landuse and Baseline (Meteorology) for 100-year ARI

Table 44: Assessment of the water level changes for different weir's height for Future Landuse and Future (Meteorology) for 100-year ARI

ARI\ Node\Link	Maximum Water Level, metre				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m/%)	Weir Height: 1.25 m	Differences (m/%)
	100-year	100-year		100-year	
CH 425 (Weir Upstream)	14.203	14.189	-0.014 (0.099%)	14.064	-0.139 (0.979%)
CH 425 (Weir Downstream)	13.787	13.789	0.002 (0.015%)	13.800	0.013 (0.094%)
Sg Chini CH 4000 (Upstream of Sg Chini)	16.118	16.117	-0.001 (0.006%)	16.109	-0.009 (0.056%)

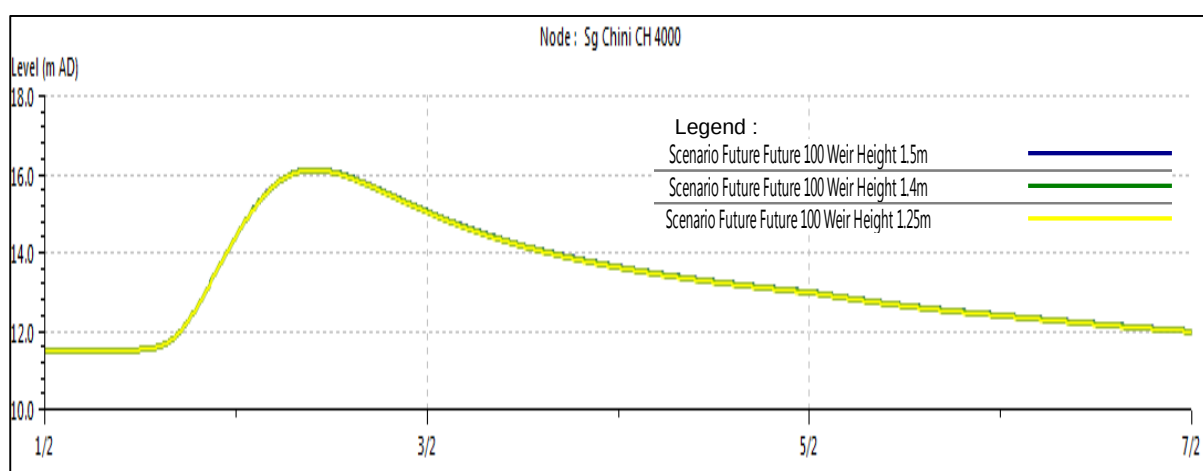


Figure 158: Comparison of water level for different weir's height for Future Landuse and Future (Meteorology) for 100-year ARI

Table 45: Assessment of the flow changes for different weir's height for Future Landuse and Future (Meteorology) for 100-year ARI

ARI\ Node\Link	Maximum Flow, m ³ /s				
	Weir Height: 1.5 m	Weir Height: 1.4 m	Differences (m ³ /s/%)	Weir Height: 1.25 m	Differences (m/%)
	100-year	100-year		100-year	
CH 425 (Weir Upstream)	67.081	67.122	0.041 (0.061%)	67.475	0.394 (0.587%)
CH 425 (Weir Downstream)	134.161	134.224	0.063 (0.047%)	134.951	0.79 (0.589%)
Sg Chini CH 4000 (Upstream of Sg Chini)	134.462	134.545	0.083 (0.062%)	135.239	0.777 (0.578%)

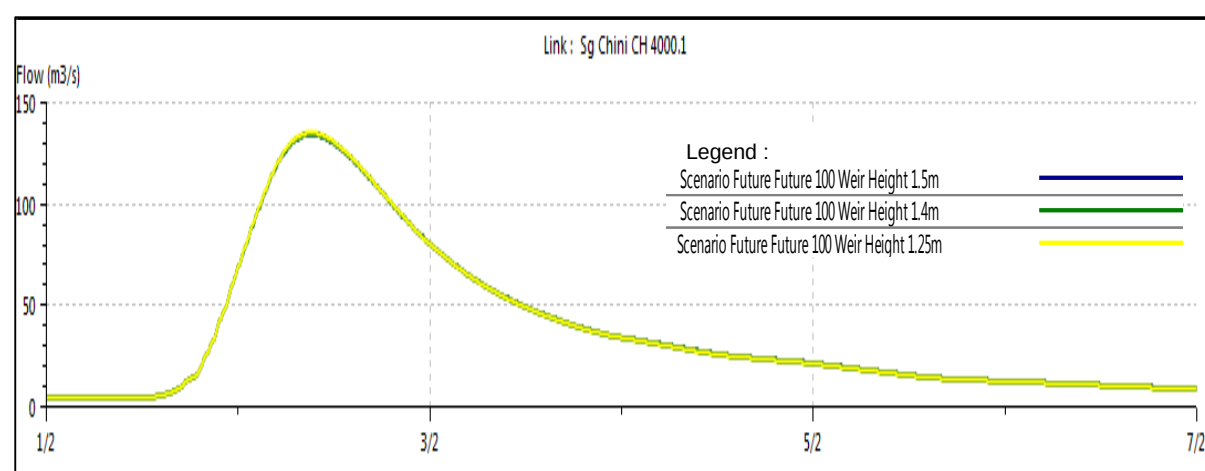


Figure 159: Comparison of flow for different weir's height for Future Landuse and Future (Meteorology) for 100-year AR

8.0 CONCLUSION AND RECOMMENDATION

8.1 Conclusion

The following conclusion can be drawn from the study:

- i. For assessment to examine the impact of landuse (from existing to future land use) for various ARIs the results show a minimal increment in both water level and flow for various ARIs under the impact of landuse change since 2010 to 2015 with minimal increase of 0.053 m (0.481%) to 0.09 m (0.637%) for water level and minimal increase of 0.563 m³/s (5.69%) to 2.929 m³/s (5.933%).
- ii. For assessment to study on the impact of climate change (from baseline to future meteorological event) for various ARIs, the results show a higher increment in both water level and flow for various ARIs under the impact of climate change with increase of 0.849 m (7.699%) to 1.903 m (13.461%) for water level and major increase of 11.003 m³/s (111.141%) to 80.755 m³/s (162.690%) for flow.
- iii. For assessment on the impact of the combination of landuse change and climate change for various ARIs. The results show a significant increment in both water level and flow for various ARIs under the impact of both landuse change and climate change with increase of 0.932 m (8.451%) to 1.981 m (14.010%) for water level and increase of 2.434 m³/s (12.290%) to 109.474 m³/s (443.448%) for flow.
- iv. For the assessment of weir modification, three different weir height were tested, namely scenario with existing weir height (1.5m), scenario with decrease of 0.1m weir height (1.4m) and scenario with decrease of 0.25m weir height (1.25m). Results for both 50 and 100-ARI show water level with a slight decrease in trend at upstream of weir and upstream of sg chini, but a slight increase at downstream of weir and downstream of Sg. Chini. However, both water level and flow increase at all locations.

8.2 Recommendations

The recommendation of appropriate measures for flood and river management has been proposed to minimize the impact of flooding and at the same time to sustain the growth of lotus population at Tasik Chini without disrupting the navigational system along Sungai Chini. Below are some of the recommendations from the study:

Option 1:

- i. Lower down the existing height of weir from 0.1 to 0.25 m, where this action can lower down the water level of the upstream of the weir and with a shallow water level, this probably could improve the environment for the healthy growth of lotuses *Nelumbo nucifera* and leading towards increasing the population of lotuses *Nelumbo nucifera*. Water depth for the optimum growth of lotuses is advisable to be less than 1.0 metre (Tuan Hj. Ghazali [Forestry Research Institute of Malaysia] personal communication, 17 March 2015). Activity of admiring the lotus in Tasik Chini would attract more tourists and boosting up the tourism sector further increase the income of local community around Tasik Chini,
- ii. Proposing that all villagers living in the flood prone areas to raise the level of building platform at least up to 18.00 metres Mean Sea Level (MSL). Otherwise, adopting floating village concept would be much beneficial. According to data captured at Kuala Sungai Chini Water Level Station, the water level rose to 18.05 metres exceeded the danger level of 14.90 metres during the December 2014 flood at Sungai Chini (JPS, 2015), and
- iii. Riverbank improvement for all the 7 feeder rivers of Tasik Chini and Sungai Chini. Riverbank improvement is needed to strengthen the river bank and reducing the chances of river bank erosion and sedimentation problem.

Refer to Figure 160 for the recommended measures under Option 1.

Option 2:

- i. Replacing the existing weir with a barrage (Width = 25 metres, Height = 8.0 metres) at downstream of Sg Chini to store excessive backwater flowing from Sungai Pahang towards Tasik Chini through Sungai Chini. This option could help to minimise the losses of flooding during wet season,
- ii. Proposing a new structure of weir at the height of 0.5 metre with 20 metres width at the discharge point from Tasik Chini to Sungai Chini. This measure would help in maintaining the water level for both the lotus growth and navigational purposes, and
- iii. Riverbank improvement for all 7 feeder rivers of Tasik Chini and Sungai Chini. Riverbank improvement is needed to strengthen the river bank and reducing the chances of river bank erosion and sedimentation problem, and

- iv. Implement integrated catchment management plan for Tasik Chini catchment (Victor and Amaravathy, 2011). Landuse changes in the upstream of the catchment will increase the flow in the lake system, thus any modification of the landform should be minimised or controlled as well to reduce the potential of erosion and sedimentation in the lake system.

Refer to Figure 161 for the recommended measures under Option 2.

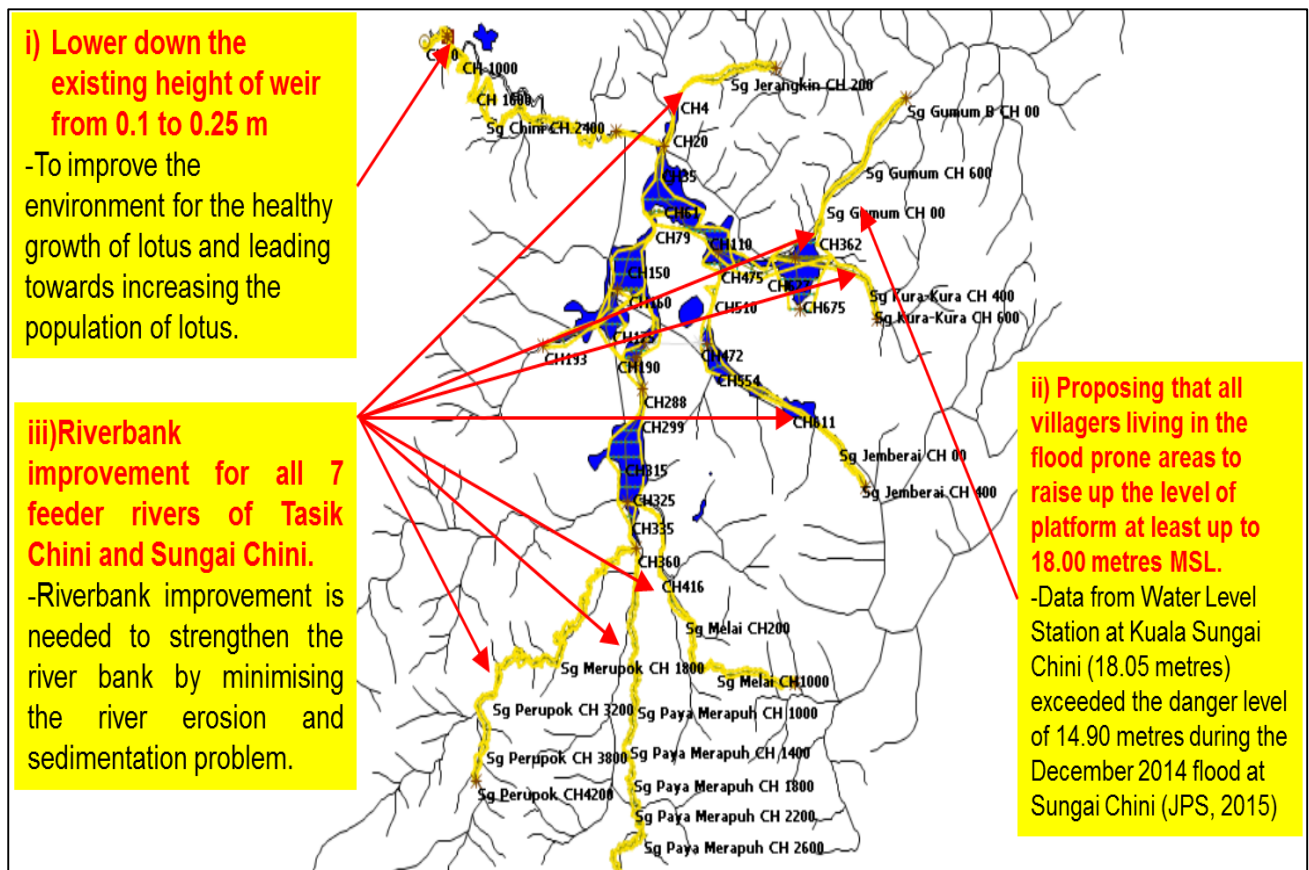


Figure 160: Recommended measures under Option 1

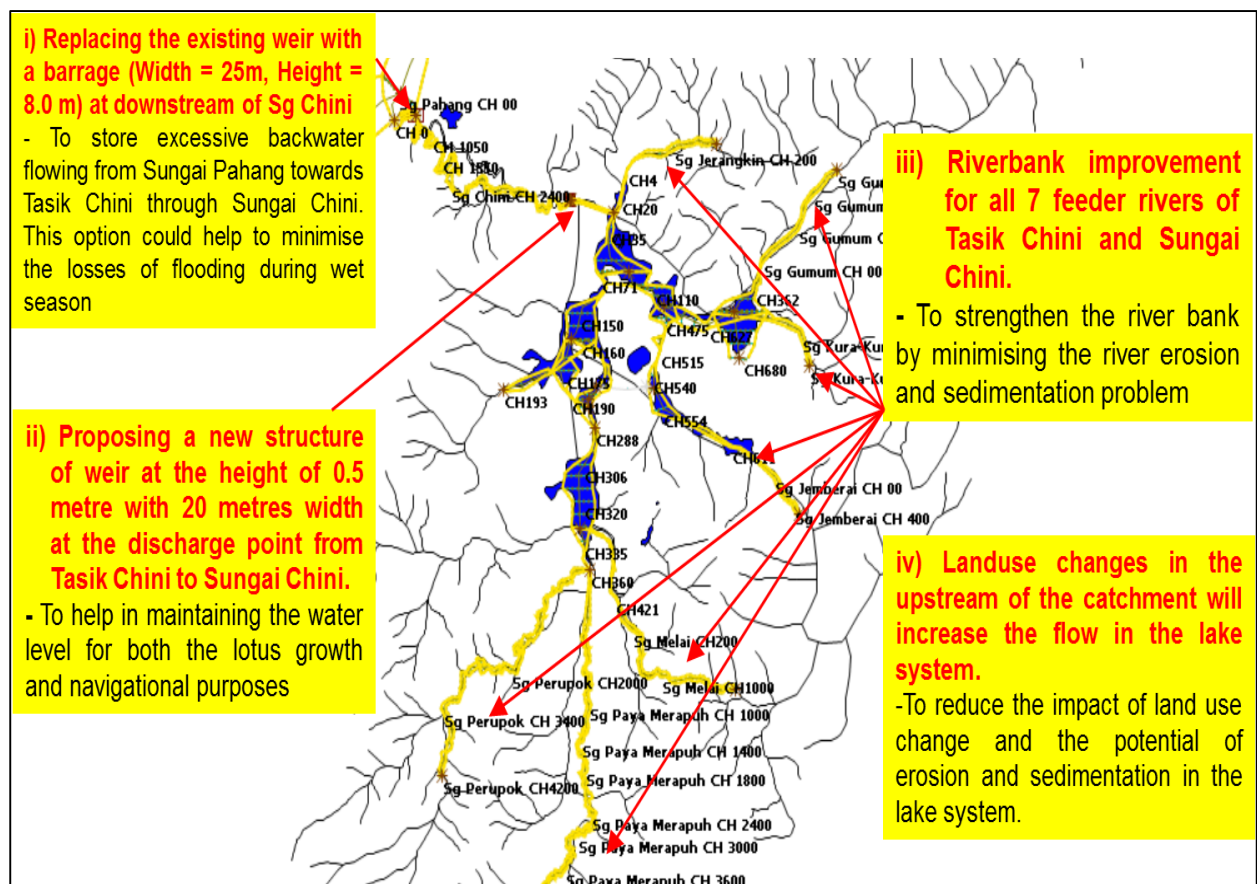


Figure 161: Recommended measures under Option 2

The overall estimated costing for the recommended flood mitigation measures is shown as in Table 46 and Figures 162 to 170.

Table 46: Estimated costing for the recommended flood mitigation measures

No.	Item	Unit	Kuantiti	Kadar (RM/Unit)	Harga (RM)
1	Riverbank Improvement	meter		2000/m	
	i. Sungai Chini		3800		7,600,000
	ii. Sg Gumum		1500		3,000,000
	iii. Sg Jerangking		1500		3,000,000
	iv. Sg Kura-Kura		1100		2,200,000
	v. Sg Jemberai		3000		6,000,000
	vi. Sg Melai		2200		4,400,000
	vii. Sg Perupok		1400		2,800,000
	viii. Sg Paya Merapuh		1500		3,000,000
2	Construction of barrage at Sg. Chini	meter	25	700,000/m	17,500,000
3	Construction of weir at Sg. Chini	meter	20	30,000/m	600,000
Jumlah Keseluruhan					50,100,000

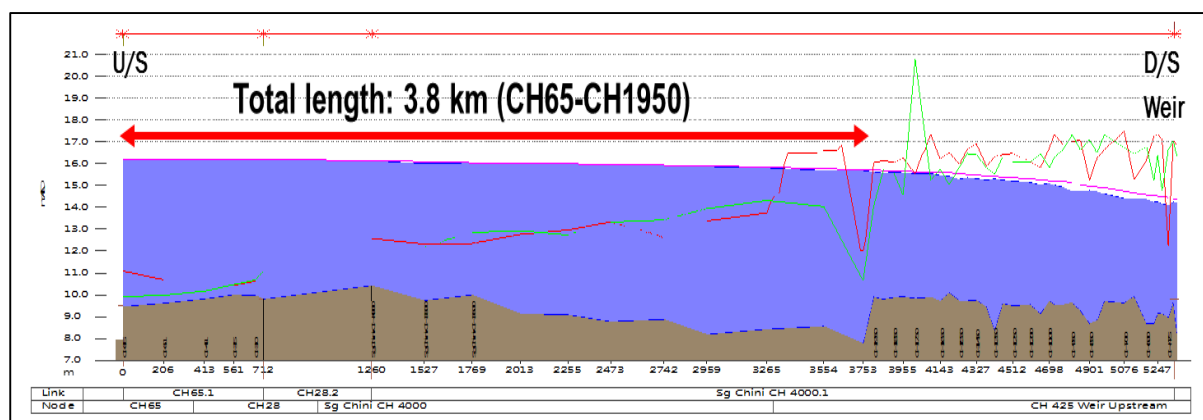


Figure 162: River Improvement for Sg Chini (From CH65 to CH1950)

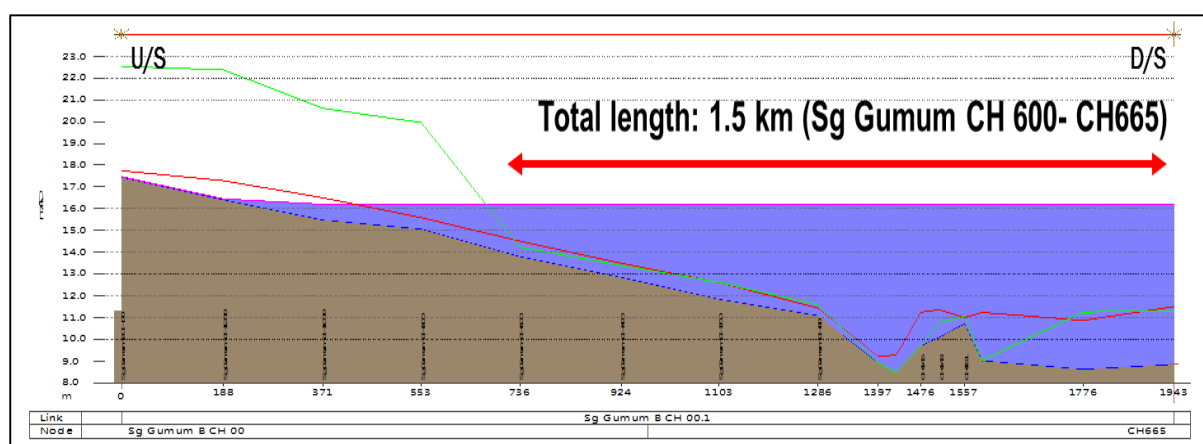


Figure 163: River Improvement for Sg Gumum (From Sg Gumum CH 600- CH665)

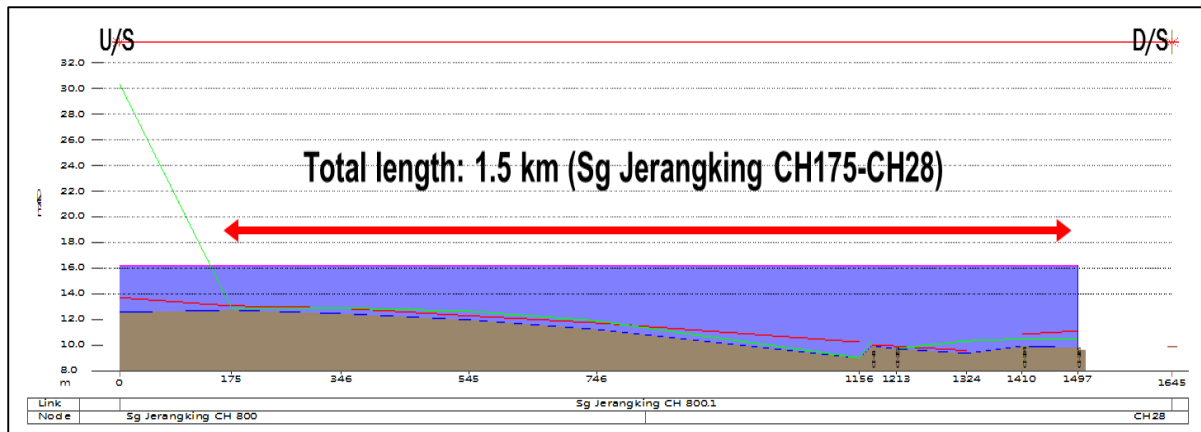


Figure 164: River Improvement for Sg Jerangking (From Sg Jerangking CH175 to CH28)

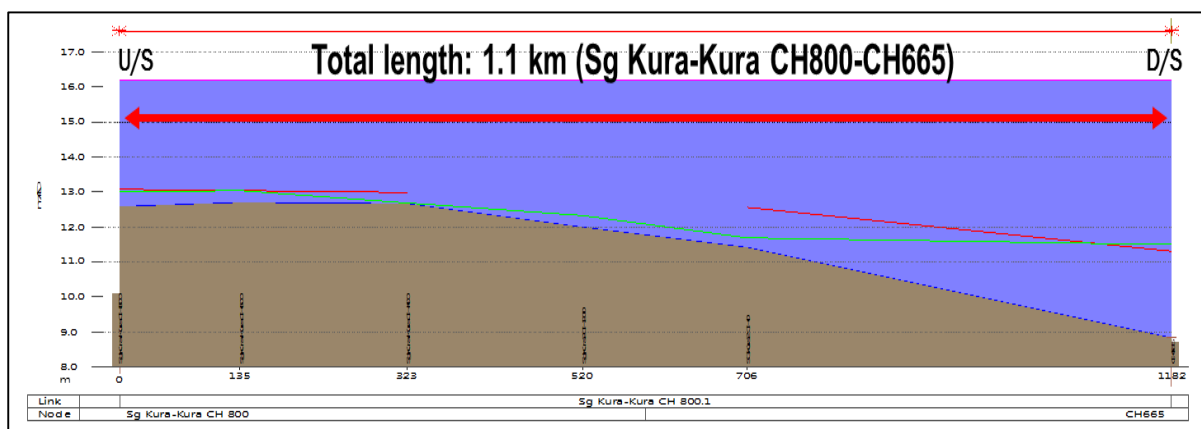


Figure 165: River Improvement for Sg Kura-Kura (From Sg Kura-Kura CH800 to CH665)

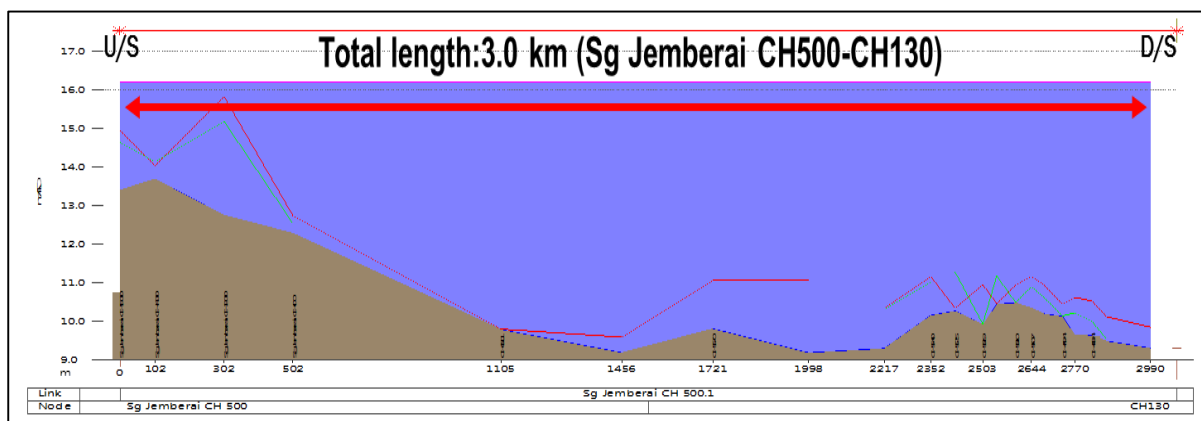


Figure 166: River Improvement for Sg Jemberai (From Sg Jemberai CH500 to CH130)

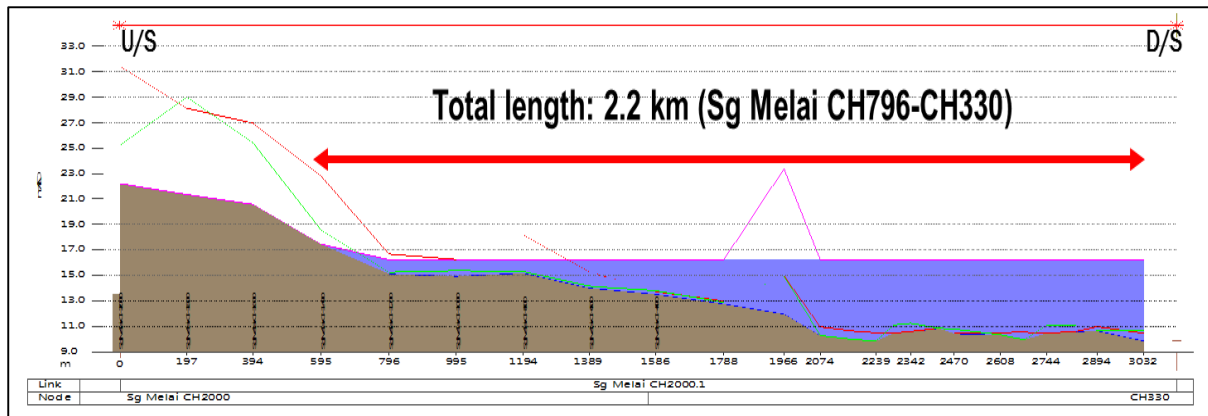


Figure 167: River Improvement for Sg Melai (From Sg Melai CH796 to CH330)

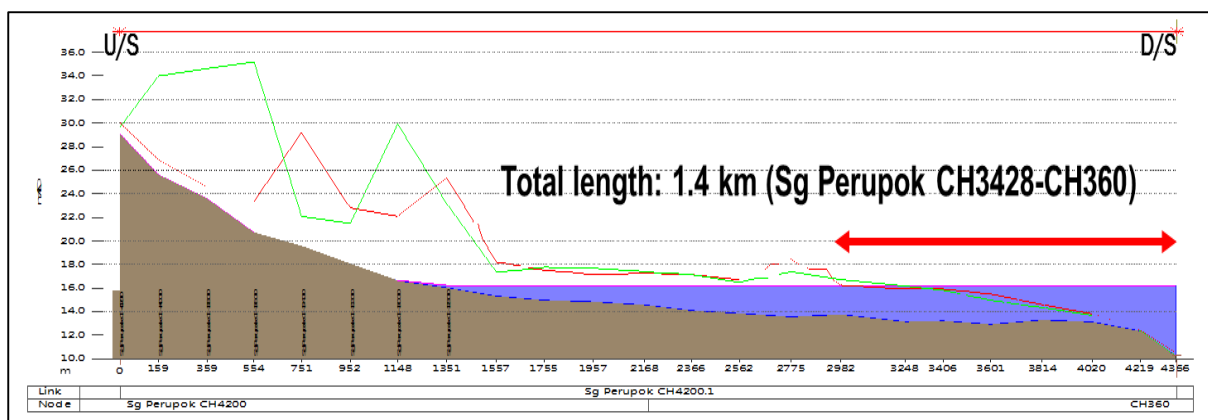


Figure 168: River Improvement for Sg Perupok (From Sg Perupok CH3428 to CH360)

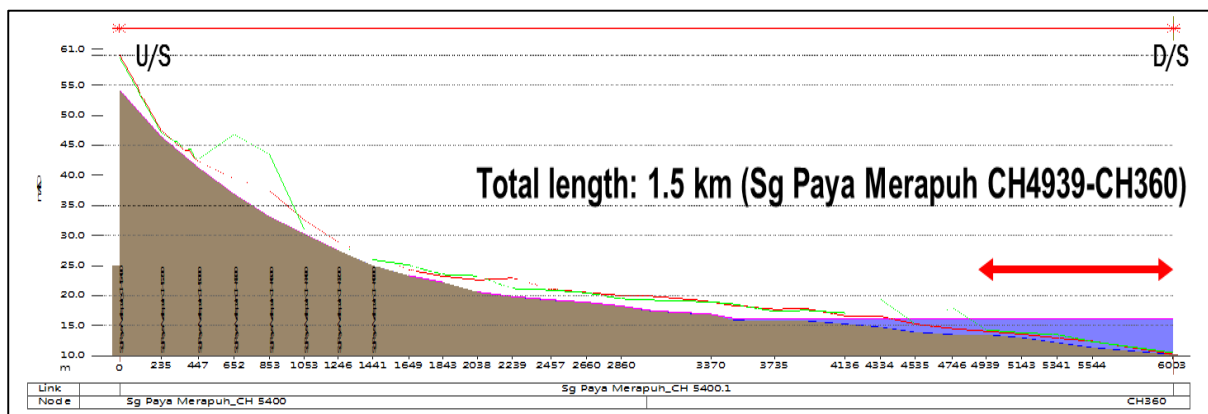


Figure 169: River Improvement for Sg Paya Merapuh (From Sg Paya Merapuh CH4939 to CH360)

9.0 REFERENCES

- Ahmad A., Mushrifah I., Shuhaimi O. and Kamsia B. (2004) Kajian kepekatan logam berat di dalam air dan tumbuhan akuatik di Tasik Chini. In: Mushrifah Idris, Khatijah Hussin, Abdul Lattif Mohammad (eds) *Khazanah Tasik Chini*. Penerbit Universiti Kebangsaan Malaysia, Bangi. (dlm. penyuntingan).
- Gasim M. B., Toriman M. E., Abd Rahim S., Islam M. S., Tan C. C. and Juahir H. 2006., Hydrology, water quality and land-use assessment of Tasik Chini's Feeder Rivers, Pahang Malaysia, School of Environment and Natural Resource Sciences Faculty Science and Technology, Universiti Kebangsaan Malaysia.
- JAS Pahang, 2011, Status kualiti air Tasik Chini 2010.
- JPS, 2011, Taklimat ringkas kepada para penyelidik dari NAHRIM untuk memahami persekitaran Tasik Chini bagi Pelan Tindakan Usaha-usaha memulihara Tasik Chini, Daerah Pekan, Pahang, Tasik Chini Resort, 6 Januari.
- JPS, 2015, Laporan Banjir Negeri Pahang Daerah Pekan.
- NAHRIM, 2014, Projek Pemuliharaan Tasik Chini Sebagai Warisan Alam dan Rizab Biosfera Malaysia: Rainfall-runoff Modelling, Hydrological Analysis and Design.
- NAHRIM, 2015, Projek Pemuliharaan Tasik Chini sebagai Warisan Alam dan Rizab Biosfera Malaysia: Rainfall-runoff Modeling, Hydrological Analysis and Design.
- Suhaimi-Othman M., Ahmad A., Mushrifah I. and Lim E. C., 2007, Seasonal Influence on Water Quality and Heavy Metals Concentration in Tasik Chini, Peninsular Malaysia, *Proceeding of Taal2007: The 12th World Lake Conference*. Pp. 300-303.
- Victor S.S. and Amaravathy S., 2011, Tasik Chini-A National Heritage in Peril, *Transparency*, 22(2/2), July-December 2011.
- Universiti Kebangsaan Malaysia (UKM), 2009. Tasik Chini Watershed, Pekan, Pahang, paper presented at the Lake Brief National Seminar, 22-23 February.