Development of Flood Level Prediction Model for Hangang River Jamsoo Bridge Using Weather Climate Data and Artificial Neural Networks

Master's course at Kangwon National University

Sung Chul, HA

2025. 03. 18

scsc0325@kangwon.ac.kr

AI 기후재난기술융합연구소
AI for Climate & Disaster Management Center

KANGWON NATIONAL UNIVERSITY

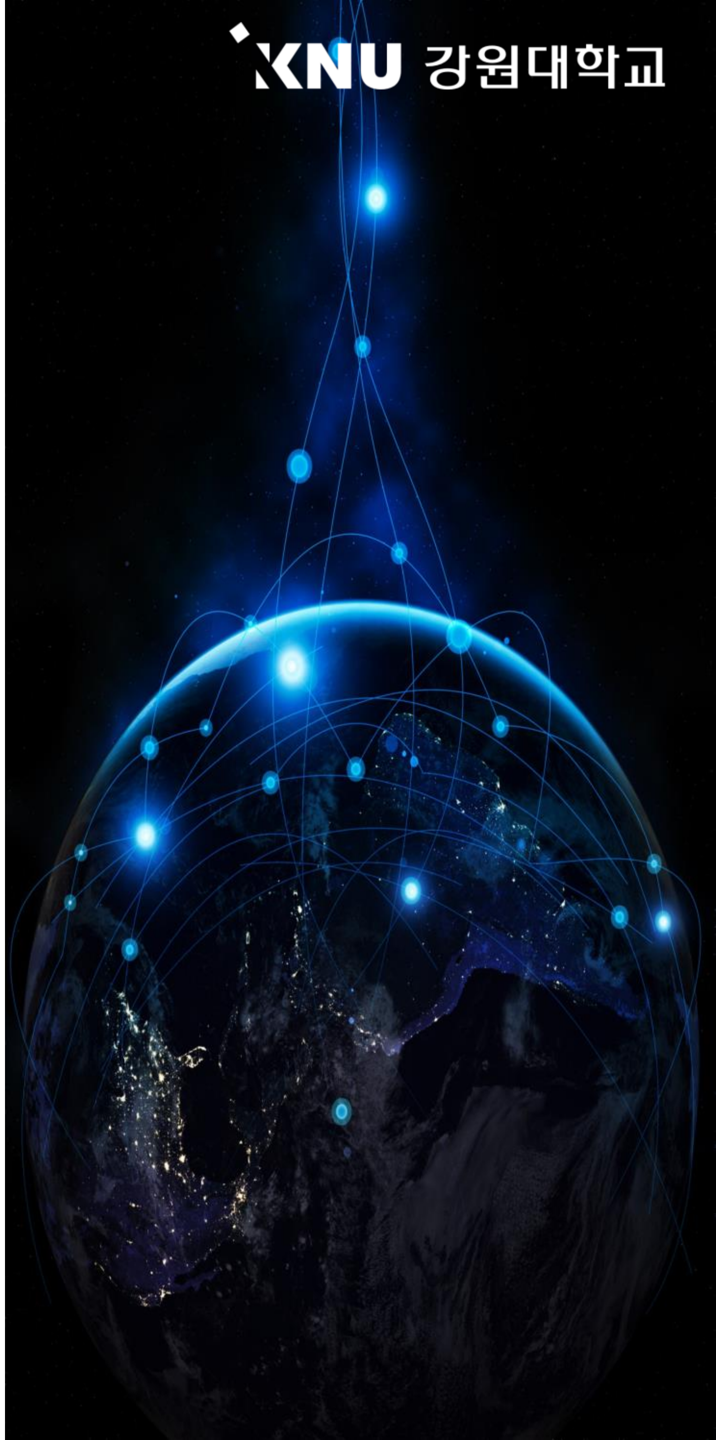
KANGWON NATIONAL UNIVERSITY

CONTENTS

1. Introduction

1.1 Research Background

1.2 Research Trends



1.1 Research Background

- Climate change is increasing the frequency and intensity of extreme rainfall events, resulting in more flood damage every year
- Need for real-time situation analysis system to reduce damage

2021
Flooding in Busan due to Typhoon Omais

Occurrence date	2021.08.24
Region	Busan
Damage	Six people isolated due to flooding of buildings and roads

2022
Flooding in Seoul torrential rains

Occurrence date	2022. 08.09
Region	Capital Area
Damage	26 fatalities and 2,280 people displaced

2023
Flooding in Osong due to heavy rains

Occurrence date	2023.07.15
Region	Osong
Damage	23 people killed as buildings, roads, and underpasses flooded

- The scale of urban flooding is growing
- Need to establish a real-time monitoring and situation analysis system
- The physical model used tends to take a long time to run and overestimates the situation

- AI is relatively simple to build input data and can utilize various input data such as figures, images, and voice.
- Various sensor data can be linked for damage monitoring and results can be derived within a short period of time.

1.1 Research Background

- Hangang River Jamsoo bridge is the first two-story bridge in Korea to connect Yongsan and Seocho districts, providing access to the city center.
- By predicting the water level of major points of the Hangang River in Seoul (such as Jamsoo bridges) according to the flood safety operation of the Paldang Dam, it is expected to prevent and minimize the damage caused by flood disasters in advance.

July 18, 2024 "Seoul Jamsu Bridge Pedestrians, Traffic Restricted...Congestion on Rush Hour"
https://www.youtube.com/watch?v=uJ5BEe42wg4

Paldang Dam discharge view
https://www.youtube.com/watch?v=uJ5BEe42wg4

Jamsoo Bridge → Submerged

1.2 Research Trends (International)

Papers	Year	Authors	Summary
Improving the Water Level Prediction of Multi-Layer Perceptron with a Modified Error Function	2023	Adel Rajab	A modified error function is presented to improve overfitting in water level prediction using Multi-Layer Perceptron (MLP) for flood warning.
Rainfall and runoff time-series trend analysis using LSTM recurrent neural network and wavelet neural network with satellite-based meteorological data: case study of Nzoia hydrologic basin	2022	Yashon O. Ouma	Collecting meteorological data consisting of precipitation, mean temperature, relative humidity, wind speed, and insolation to simulate runoff in the Nzoia River Basin, Kenya Train LSTM and wavelet neural networks Results of runoff simulation show that precipitation is the most important meteorological data to the outcome
Flood Forecasting by Using Machine Learning: A Study Leveraging Historic Climatic Records of Bangladesh	2017	Oh, S. H	AI models are trained on 16 different weather data sets, including daily temperatures, to predict flooding in Bangladesh Out of 11 AI models, LSTM (Long Short-Term Memory) performed the best

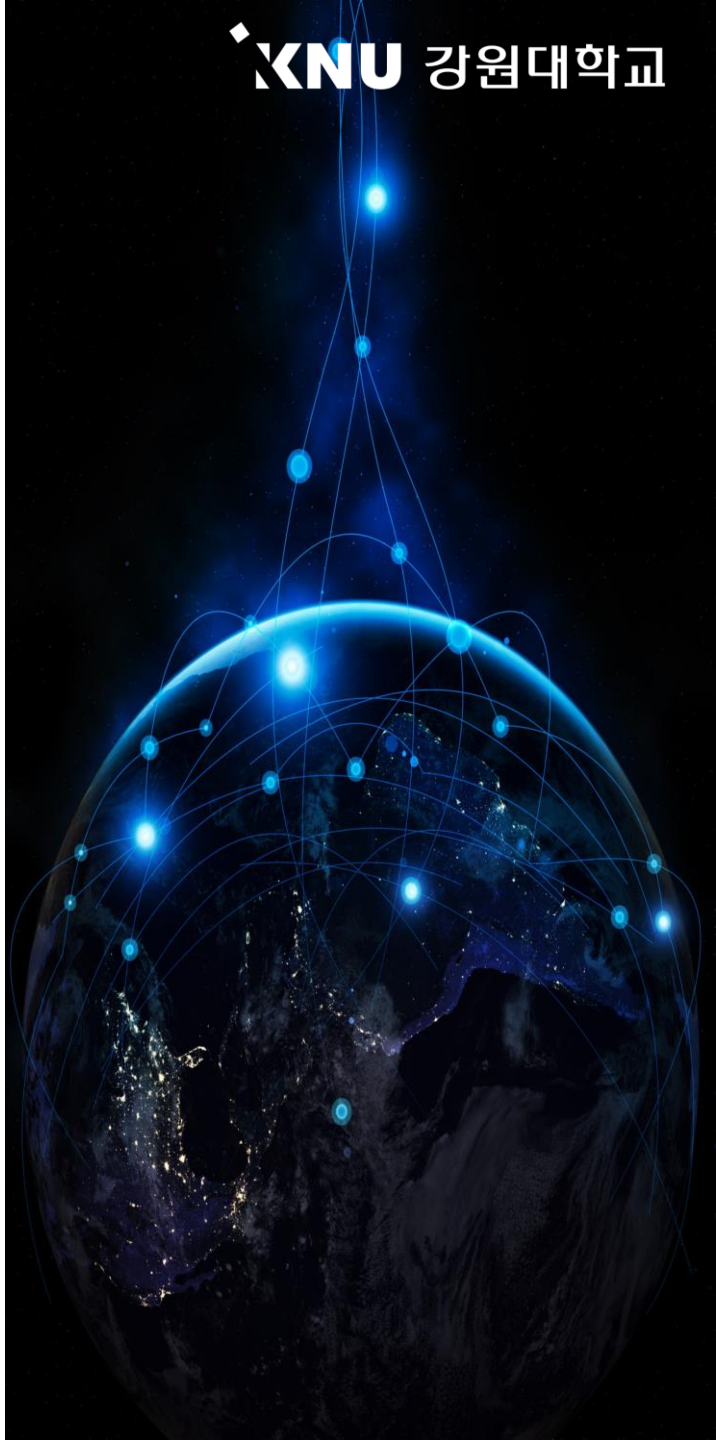
Research using LSTM and other methods is ongoing,
and research using AI is actively being conducted around the world.

2. Theory and Methods

2.1 LSTM(Long Short-Term Memory)

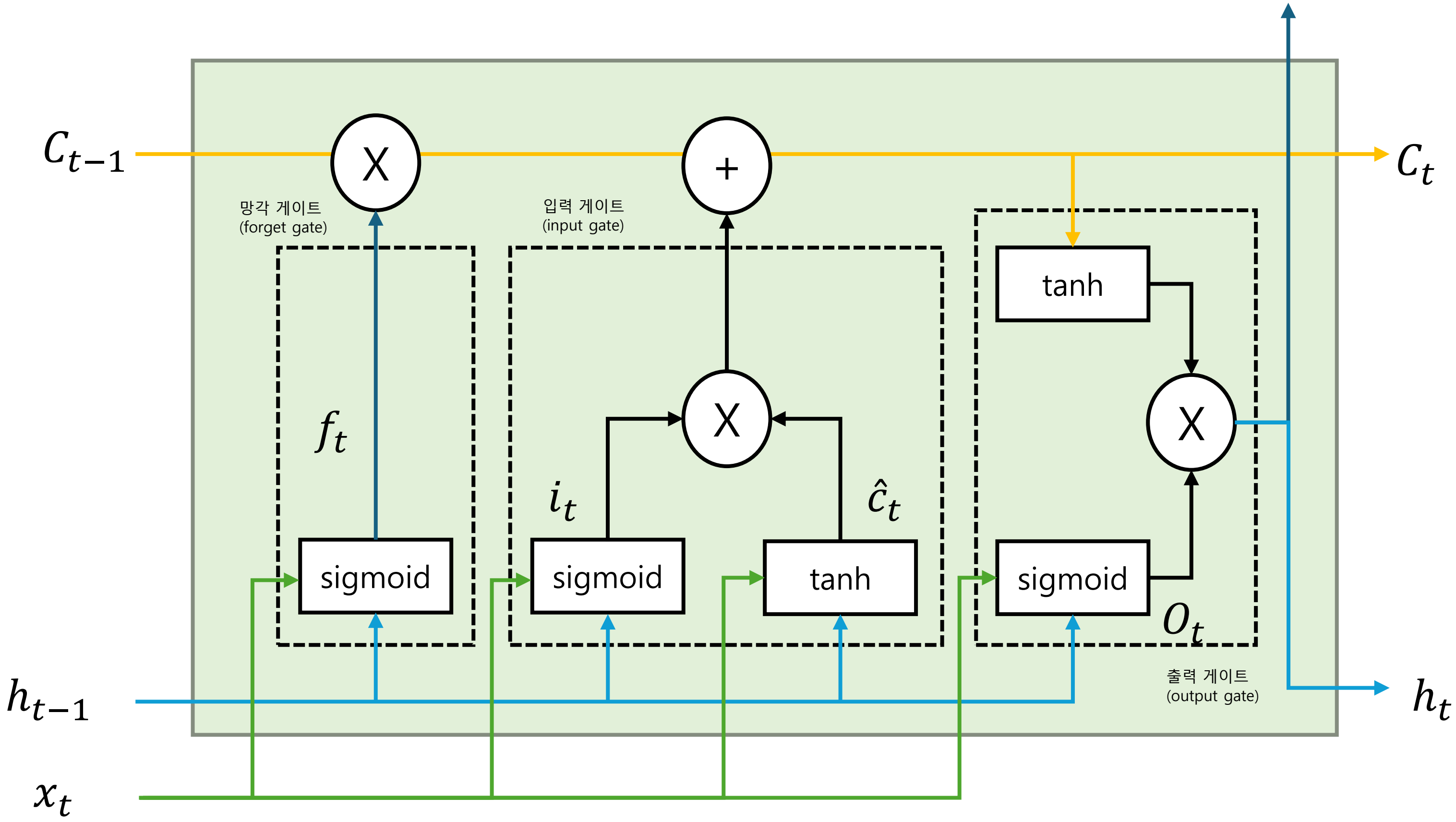
2.2 Bi-LSTM (Bidirectional Long Short-Term Memory)

2.3 Research Flowchart



2.1 LSTM(Long Short Term-Memory)

- Long short-term memory (LSTM) is a model that improves on the long-term dependency issues of RNNs, calculating how much of the past to forget or remember based on information from the present moment, and performs better on longer sequences than RNNs.



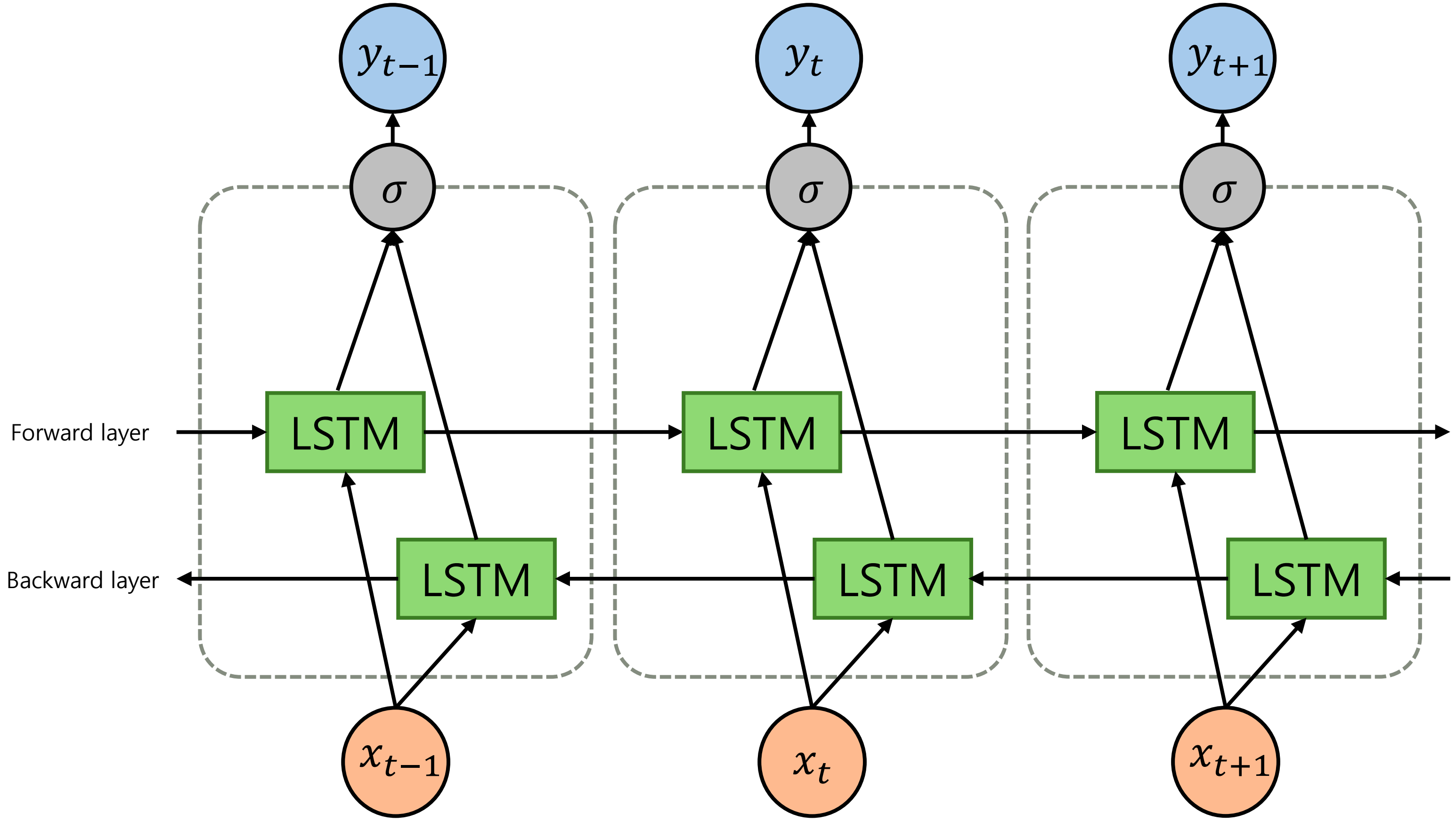
Structure of an LSTM
consists of cells and gates, where cells store sequences of data, and gates manipulate the state of the cells.

An LSTM consists of a forget gate, an input gate, and an output gate.
Each gate goes through several activation functions to forget or remember past data.

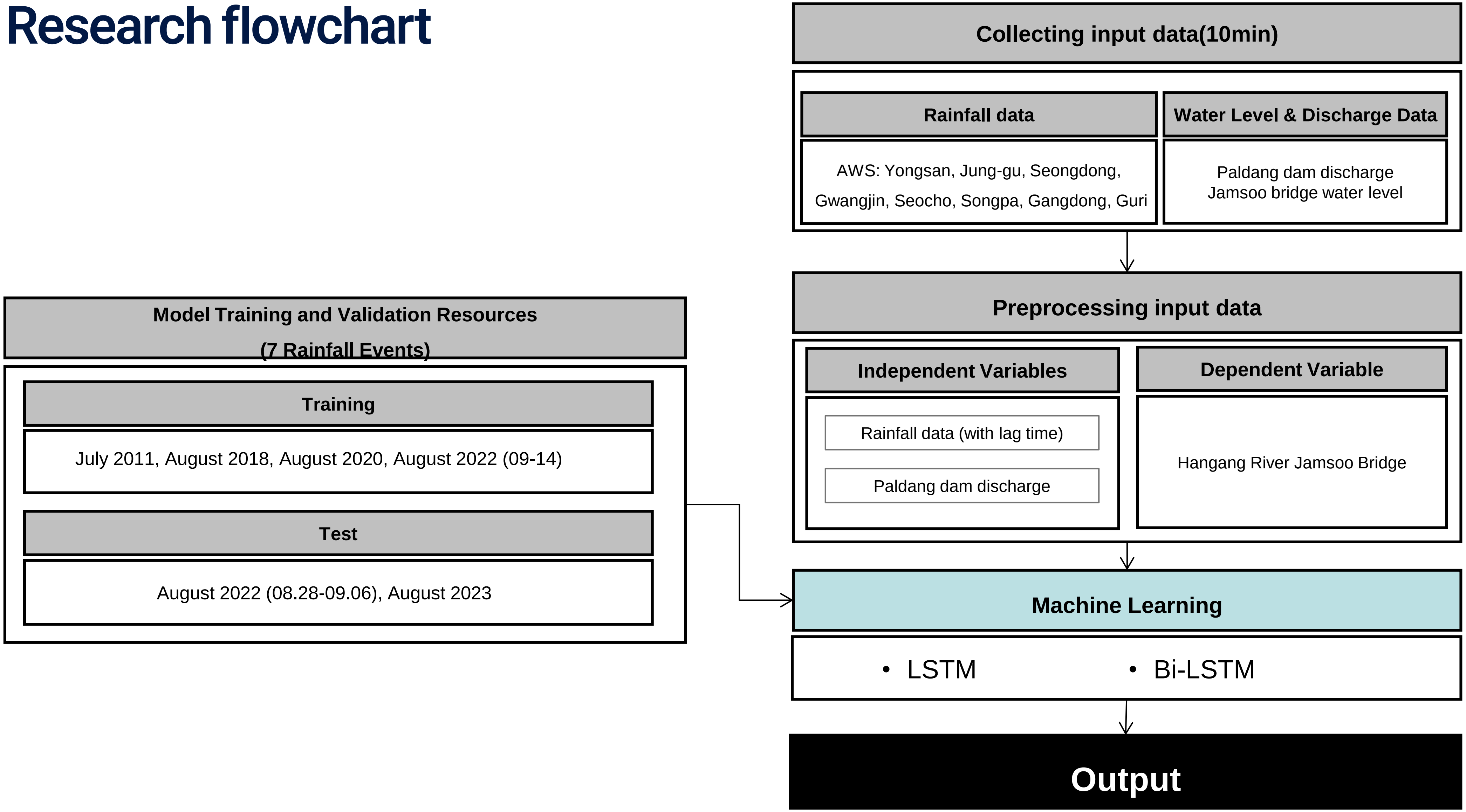
How LSTM Works
1. Cell State
2. 2. Forget Gate
3. 3. Input Gate
4. 4. Output Gate

2.2 Bi-LSTM(Bidirectional-LSTM)

- Bi-LSTM models incorporate forward and backward LSTMs that process input sequences in both directions. The outputs of each LSTM layer are concatenated to create a sequence that incorporates both past and future context, allowing the model to account for complex temporal dependencies



2.3 Research flowchart



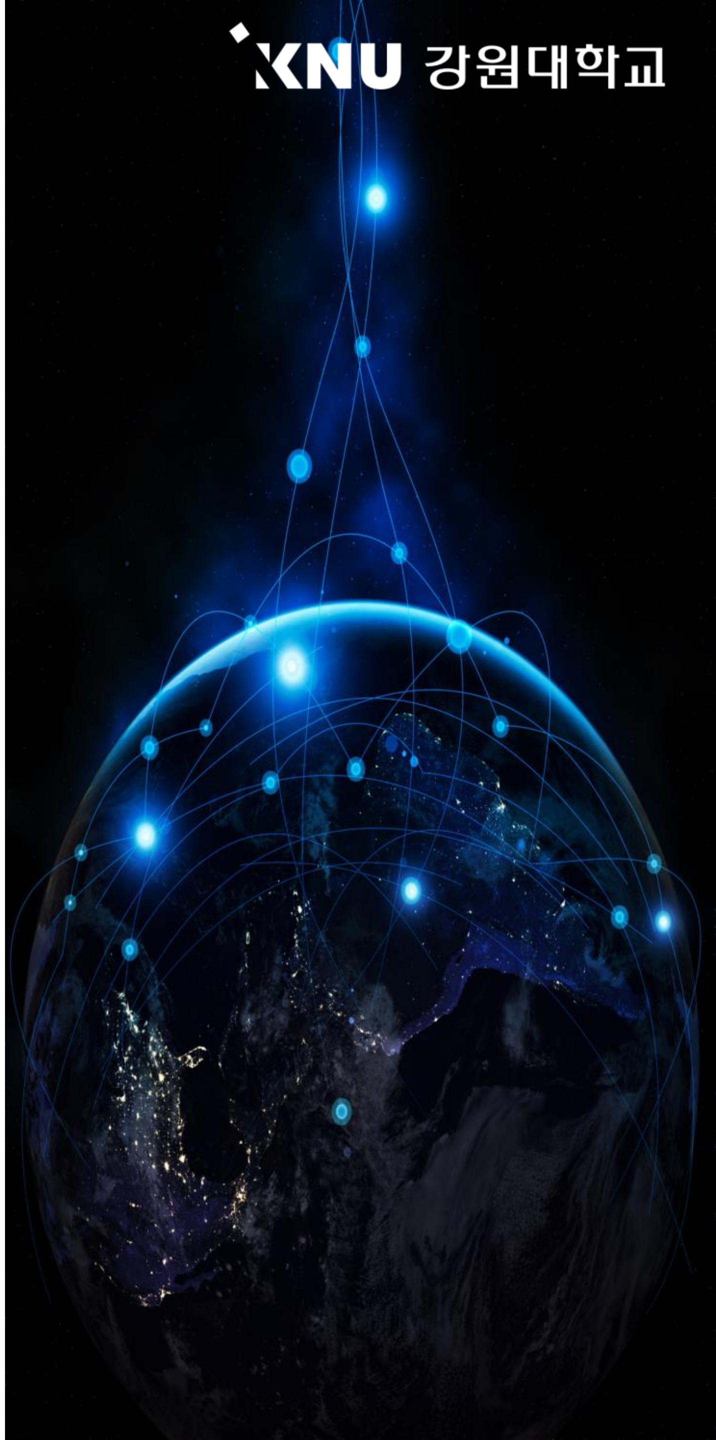
3. Apply and Analysis

3.1 Research a Target Watershed

3.2 Analytical Data

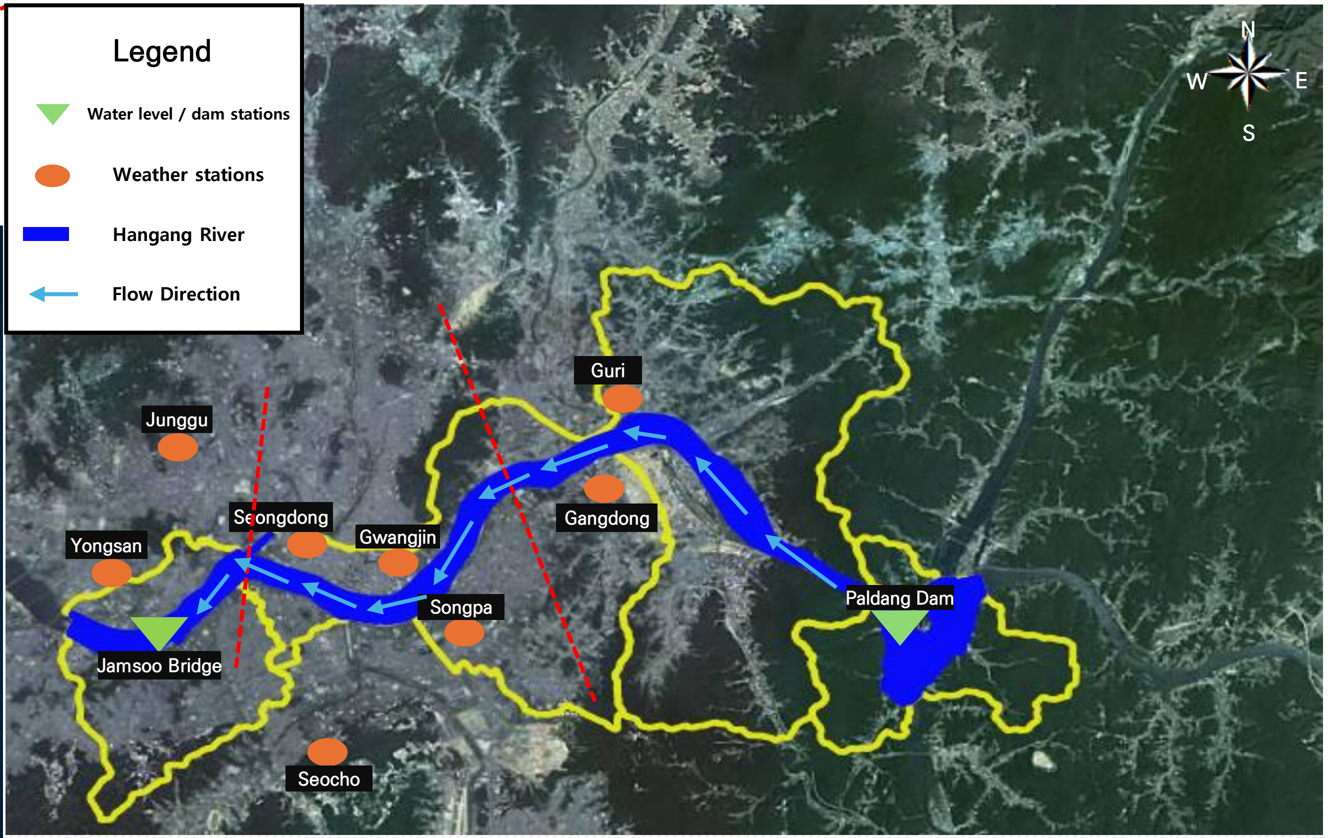
3.3 Model Construction

3.4 Model Evaluation Methods

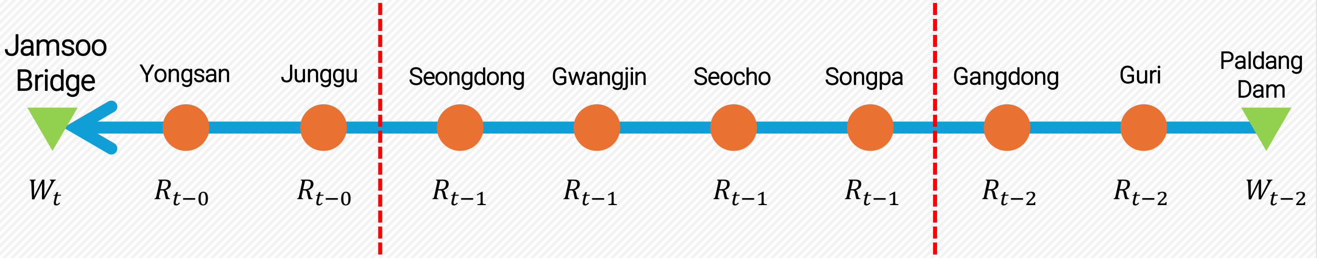


3.1 Target watershed

Hangnag River, Seoul (Jamsoo bridge)



※ 2 hours for Paldang dam, Guri, Gangdong, and Observatory, 1 hour delay for Songpa, Gwangjin, Seocho, Seongdong stations



3.2 Analytical Data

- Collected data from a total of 7 rainfall events
- Collected AWS weather observation data (rainfall) from Korea Meteorological Administration and water level and dam discharge data from Hangang River Flood Control Center
- Categorized each rainfall event as Event 1~7 and used Event1~5 as Training and Event 6~7 as Test

Rainfall Events

Event	Rainfall events	Rainfall duration (hour)	Peak water level (m)	Accumulative rainfall (mm)
Event 1	2011 .07	60	11.03	475.75
Event 2	2018.08	50	7.06	167.75
Event 3	2020. 08. 02 ~ 07.	61	11.53	248.6
Event 4	2020. 8. 09 ~ 15.	38	9.11	219.65
Event 5	2022. 08.	56	9.7	408.7
Event 6	2022. 08. 26.~09. 06.	29	8.88	178.25
Event 7	2023. 07.	56	8.42	194.8

Weather station status

Station Name	Station No,	Observation start date	X (N)	Y (E)	Notes
Yongsan	415	1994. 12. 09.	548598.67	21089.5121	Rainfall Station
Junggu	419	1994. 12. 10.	552219.7596	22146.2635	
Seongdong	421	2000. 08 . 22.	551551.8666	26684.8883	
Gwangjin	413	1994. 12. 08.	549937.4107	30821.9001	
Seocho	401	1994. 12. 04.	544627.8532	25404.2175	
Songpa	403	1994. 12. 05.	547483.9206	31717.6119	
Gangdong	402	1994. 12. 04.	552288.3041	36083.216	
Guri	569	1993. 10. 20.	555229.0026	37201.7819	

Water level and dam station status

Station Name	Station No.	Observation start date	X (N)	Y (E)	Notes
Paldang Dam	1303680	1992. 05. 01	537671	214614	Dam
Jamsoo Bridge (Water Leverl)	1018680	1984. 06. 23	548304. 3197	22762.8 389	Water Level Station

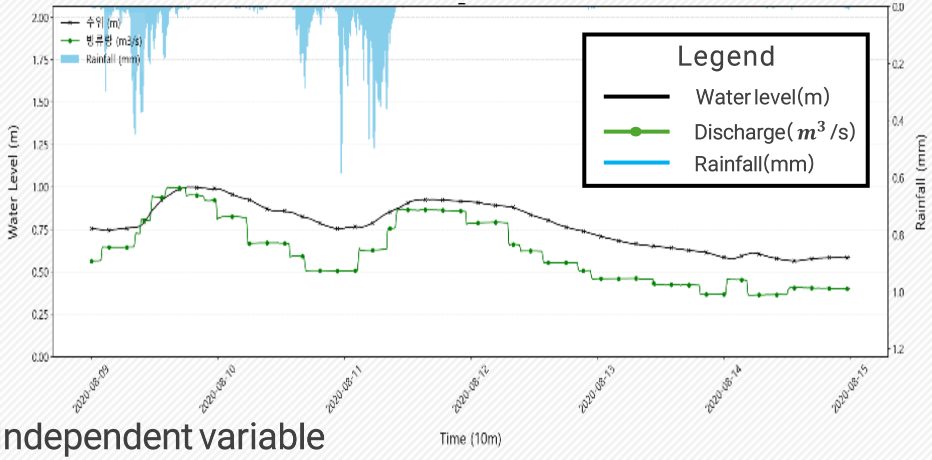
Jamsoo Bridge Entry Control Criteria

Classfication	Jamsoo bridge water level (m)	Jurisdictions
Walking Restrictions	5.5	Yongsan (north end of Jamsoo Bridge) Seocho (south end of Jamsoo Bridge)
Vehicle Restrictions	6.2	Yongsan (Riverside 3 Road Entrance) Seocho (south end of Jamsoo Bridge) Banpo Bridge South Approach (Seocho)
Bridge Submerged	6.5	-

3.2 Analytical Data

- Predict 6 hours ($t+36$) after the current time by inputting 6 hours of past data (10 minutes)
- Apply a time difference of 6 hours (t-36) to the dependent variable (Jamsoo bridge water level) and build a prediction model by learning it.

Inputs (rainfall & discharge)



Independent variable

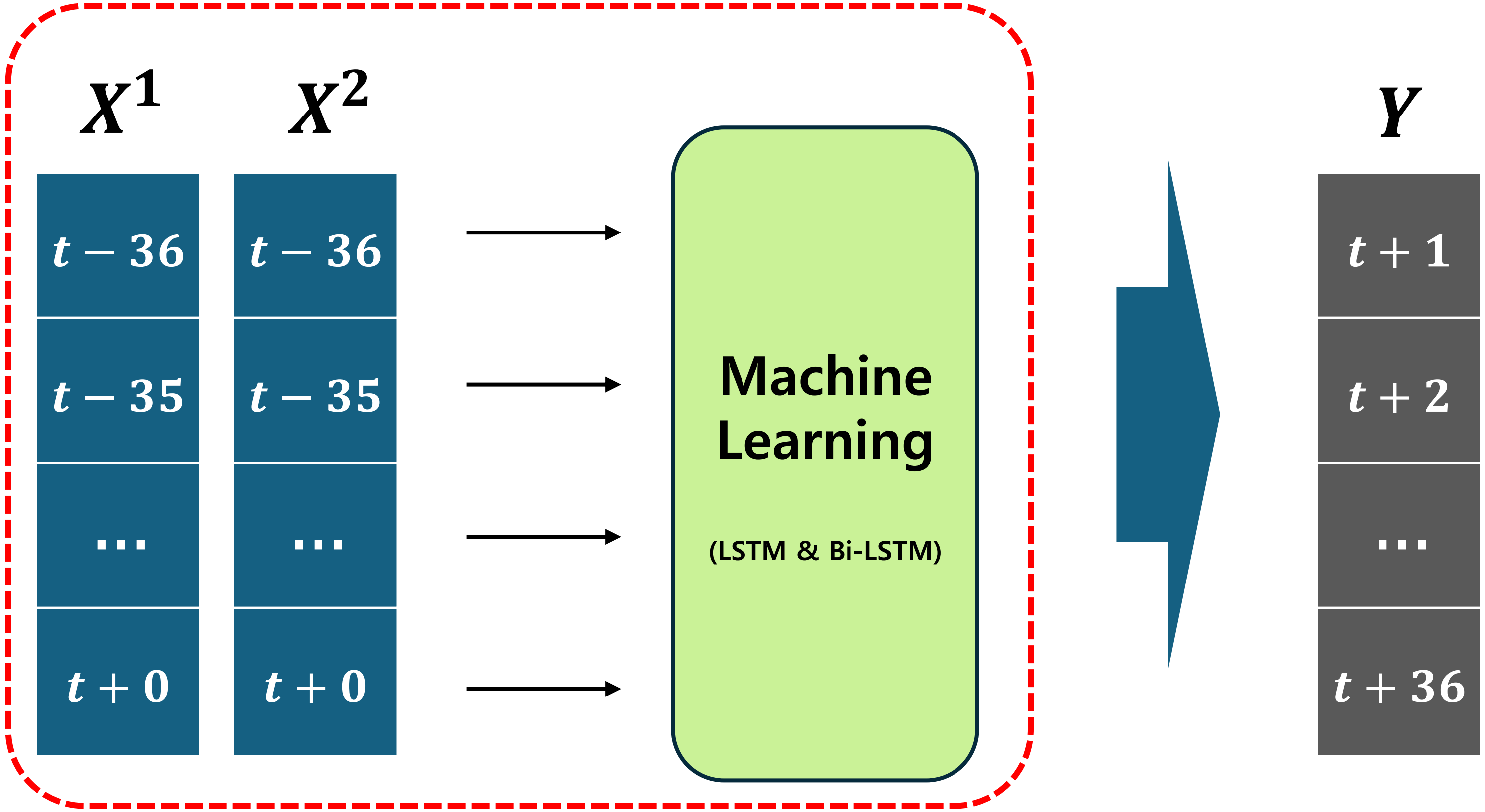
X^1_{t-36}	X^1_{t-35}	…	X^1_{t+0}
X^2_{t-36}	X^2_{t-35}	…	X^2_{t+0}

Dependent variable

Y_{t+1}	Y_{t+2}	…	Y_{t+36}

X : Independent variable
Y : Dependent variable (Jamsoo bridge water level)
X^1 : Rainfall
X^2 : Discharge
t : Time

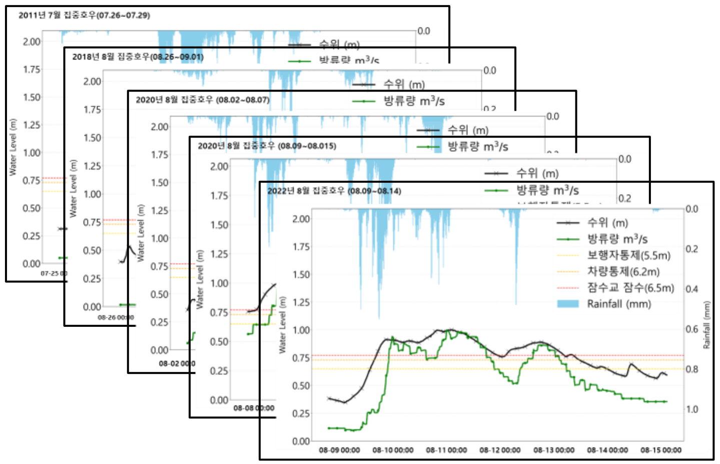
Predict 6 hours into the future by training data with a 6-hour delay ※ t+0 is the current time



3.2 Analytical Data

- Sequentially train the model with Training data (Events 1-5)
- After training with Events 1-5, input Test data (Events 6-7) and compare the output water level results

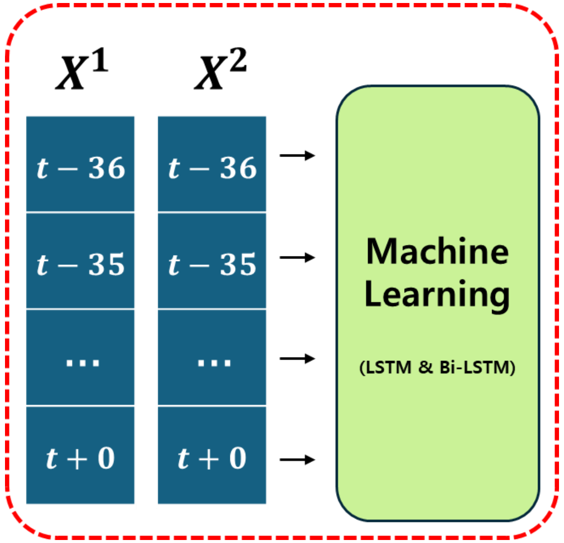
Training Data



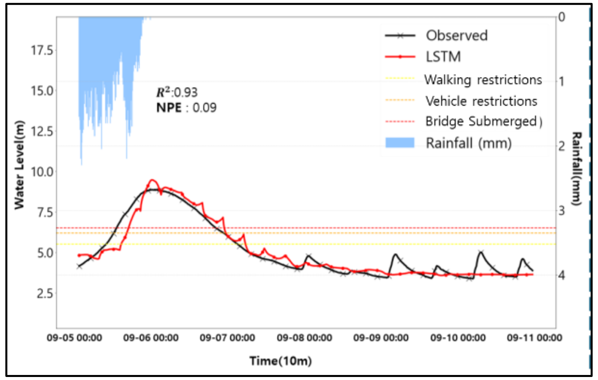
Model training

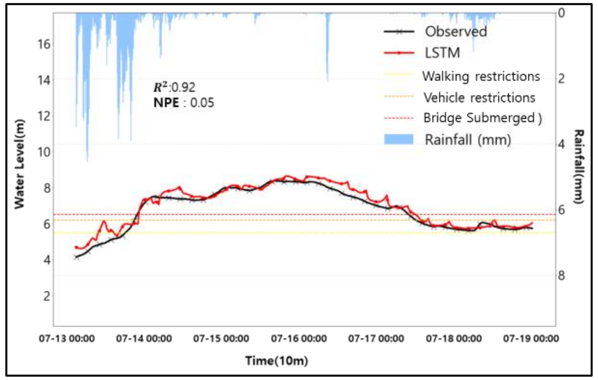
Event 1 -> Event 2 -> Event 3 -> Event 4 -> Event 5

Learn Events 1-5



Test the model using Events 6 and 7





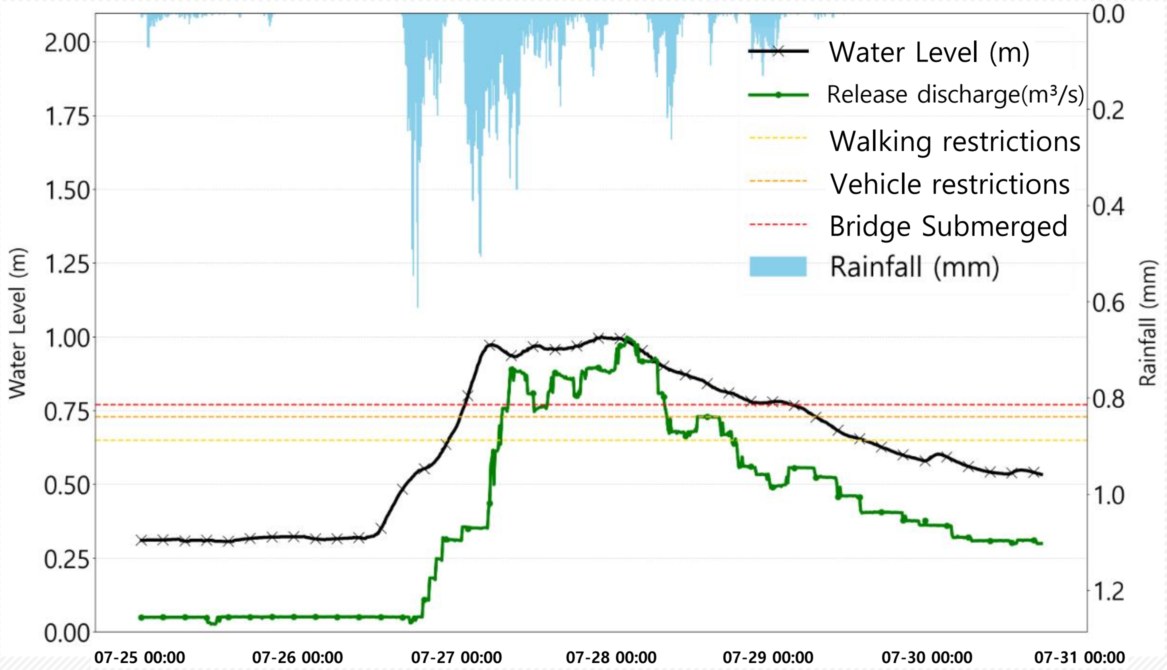
3.2 Analytical Data (Training)

- The analysis data uses the observed water level (Jamsoo bridge), AWS rainfall data, and Paldang Dam discharge in 10-minute increments.
- Collected water level data from Hangang River Flood Control Center and AWS rainfall data from Korea Meteorological Administration(KMA)

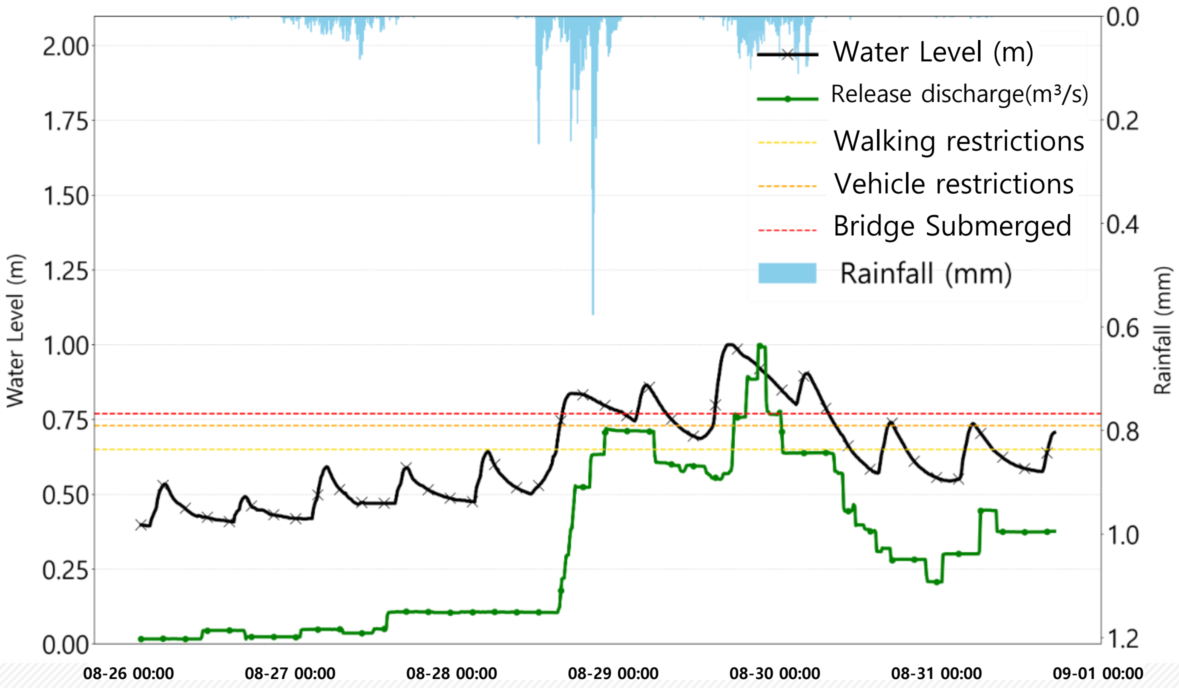
Event 1	Event 2	Event 3	Event 4	Event 5
2011. 07	2018. 08	2020. 08	2020. 08	2022. 08

Time series of water level and rainfall observations

※ Converted to a value between 0 and 1 because discharge and water level have different units.



July 2011 Heavy Rainfall (07.26-07.29)



August 2018 Heavy rainfall (08.26-09.01)

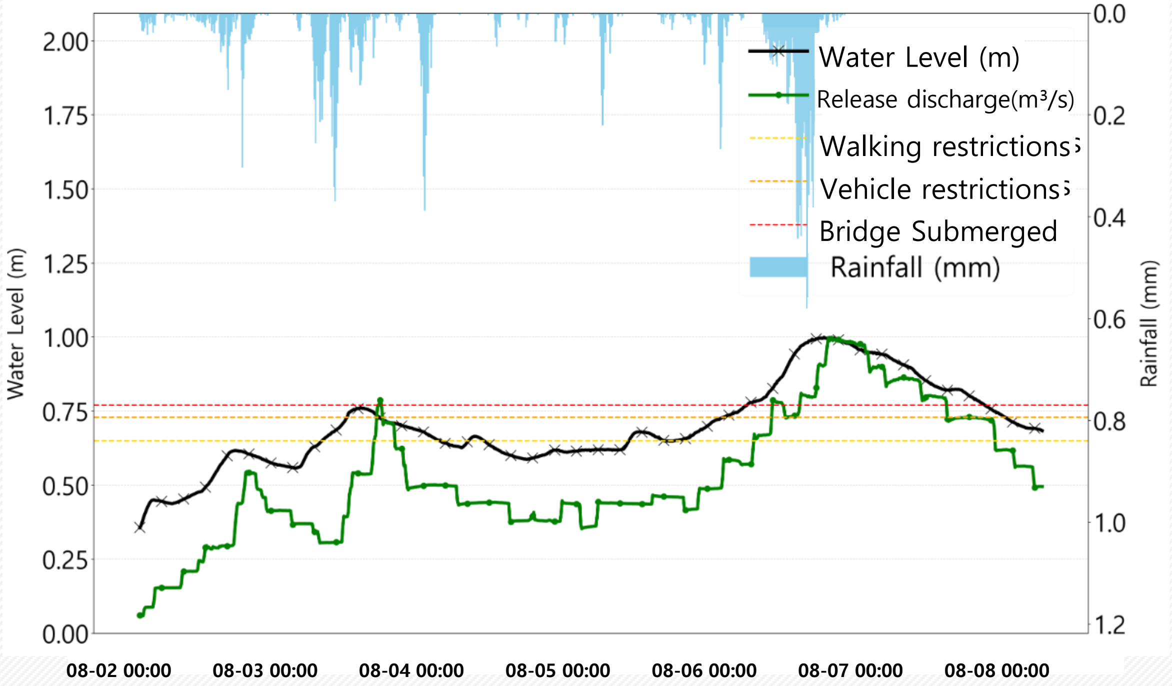
3.2 Analytical Data (Training)

- The analysis data uses the observed water level (Jamsoo bridge), AWS rainfall data, and Paldang Dam discharge in 10-minute increments.
- Collected water level data from Hangang River Flood Control Center and AWS rainfall data from Korea Meteorological Administration(KMA)

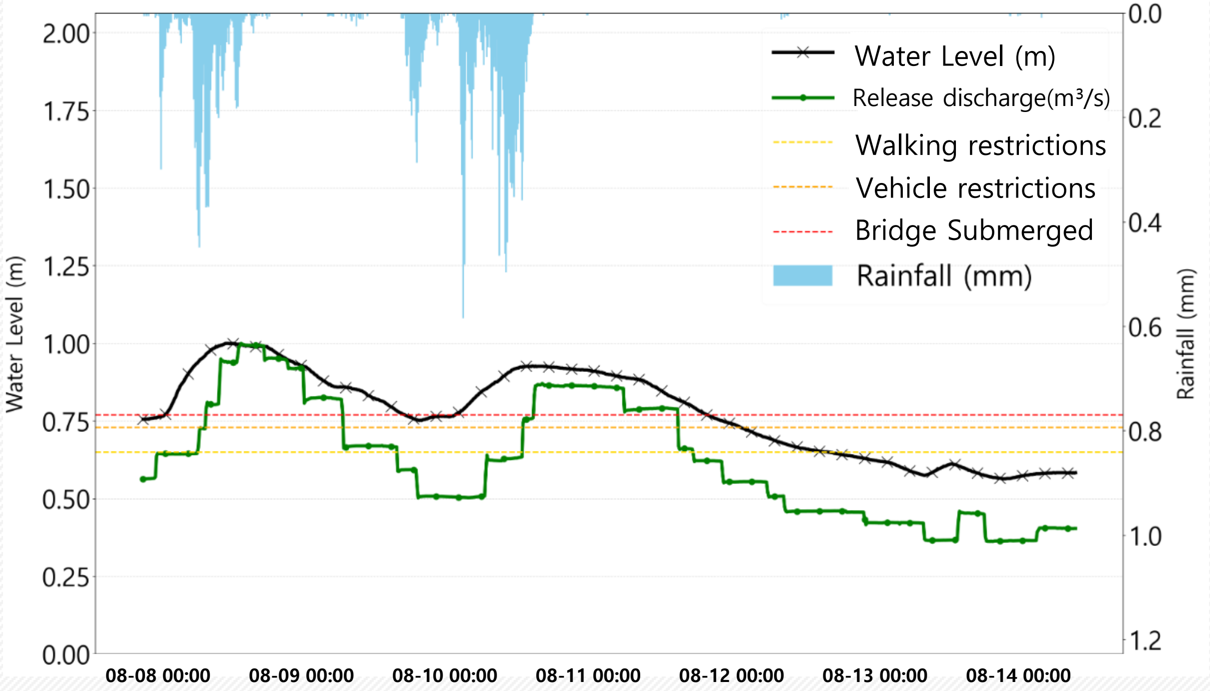
Event 1	Event 2	Event 3	Event 4	Event 5
2011. 07.	2018. 08.	2020. 08.	2020. 08.	2022. 08.

Time series of water level and rainfall observations

※ Converted to a value between 0 and 1 because discharge and water level have different units.



August 2020 Heavy rainfall (08.02-08.07)



August 2020 Heavy rainfall (08.09-08.15)

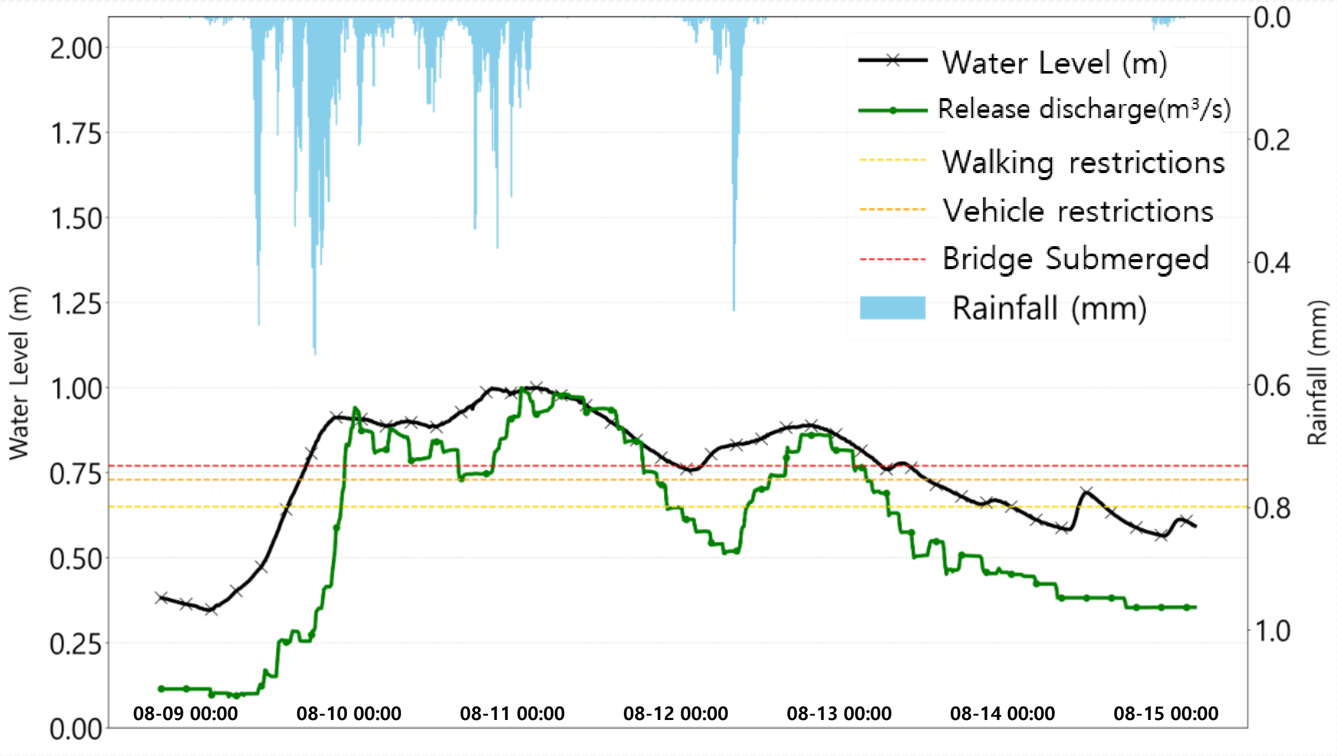
3.2 Analytical Data (Training)

- The analysis data uses the observed water level (Jamsoo bridge), AWS rainfall, and Paldang dam discharge in 10-minute increments.
- Collected Jamsoo bridge water level data from Hangang River Flood Control Center and AWS rainfall data from Korea Meteorological Administration

Event 1	Event 2	Event 3	Event 4	Event 5
2011. 07.	2018. 08.	2020. 08.	2020. 08.	2022. 08. (9th-14th)

Time series of water level and rainfall observations

※ Converted to a value between 0 and 1 because discharge and water level have different units.



August 2022 Heavy Rainfall (08.09-08.14)

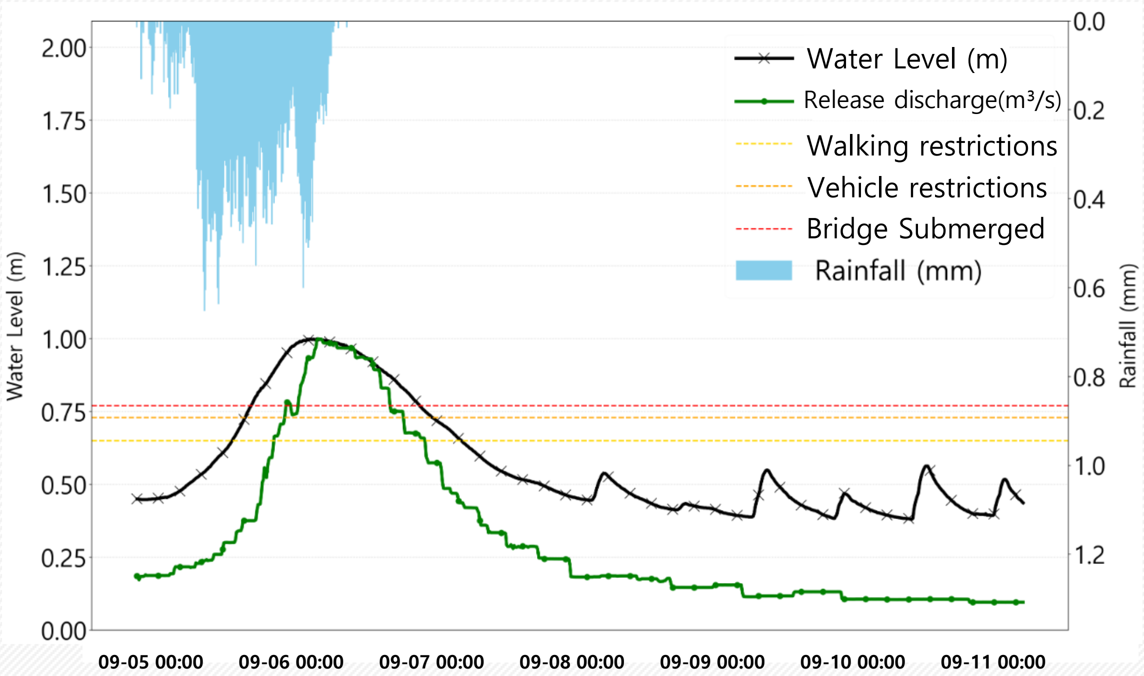
3.2 Analytical Data (Test)

- The analysis data uses the observed water level (Jamsoo bridge), AWS rainfall, and Paldang dam discharge in 10-minute increments.
- Collected Jamsoo bridge water level data from Hangang River Flood Control Center and AWS rainfall data from Korea Meteorological Administration

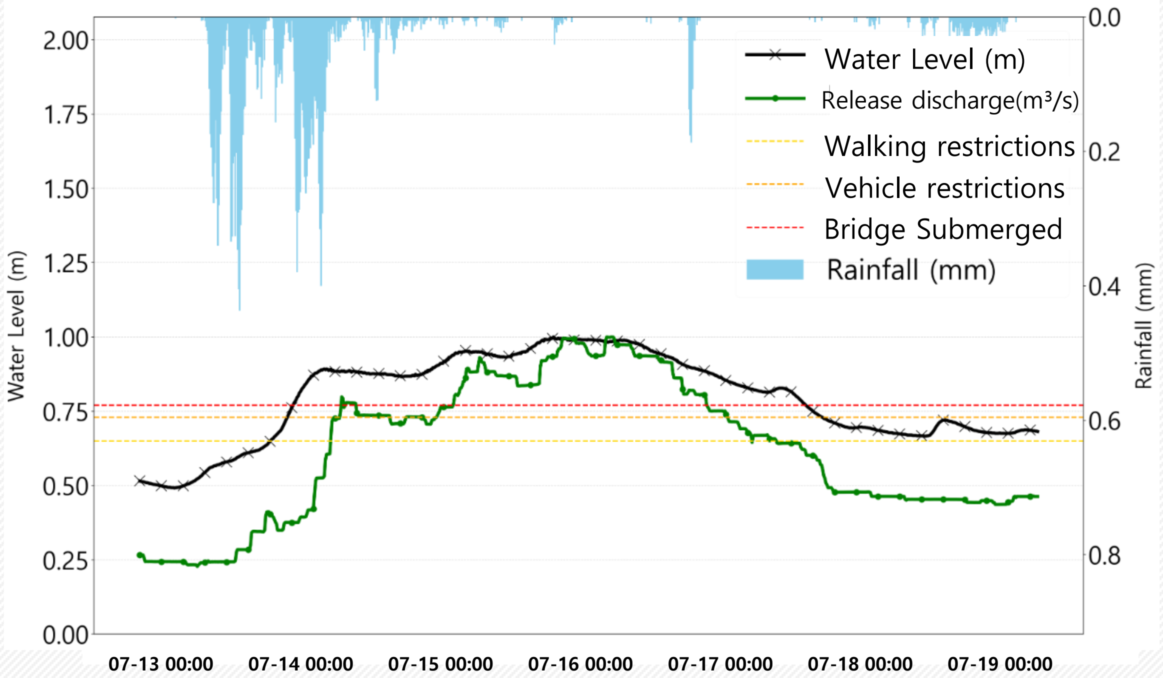
Event 6	Event 7
Typhoon Hinamno, 2022 (August 28-September 6)	2023. 07

Time series of water level and rainfall observations

※ Converted to a value between 0 and 1 because discharge and water level have different units.



Typhoon "Hinnamno" in 2022 (08.28-09.06)



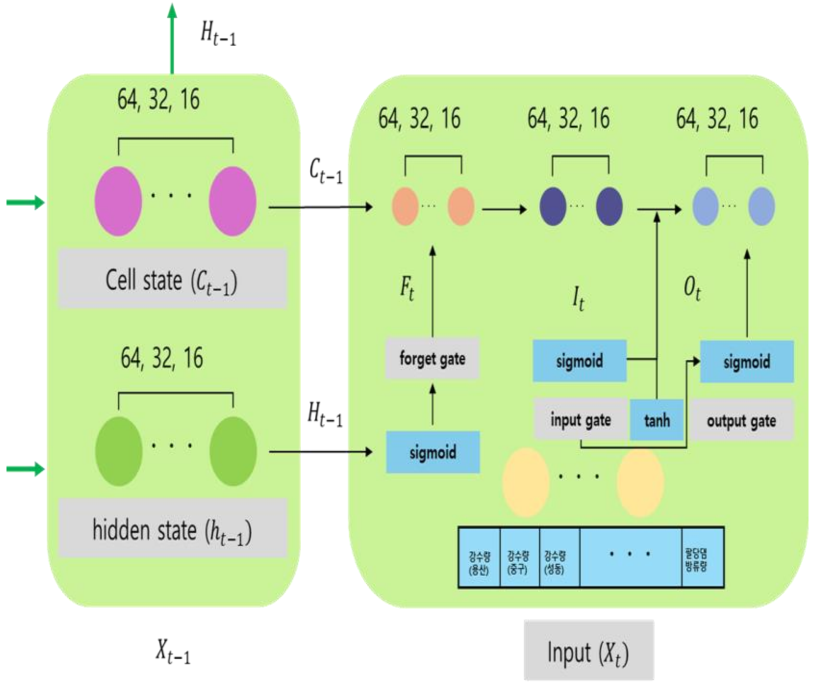
July 2023 Heavy Rainfall (07.13-07.18)

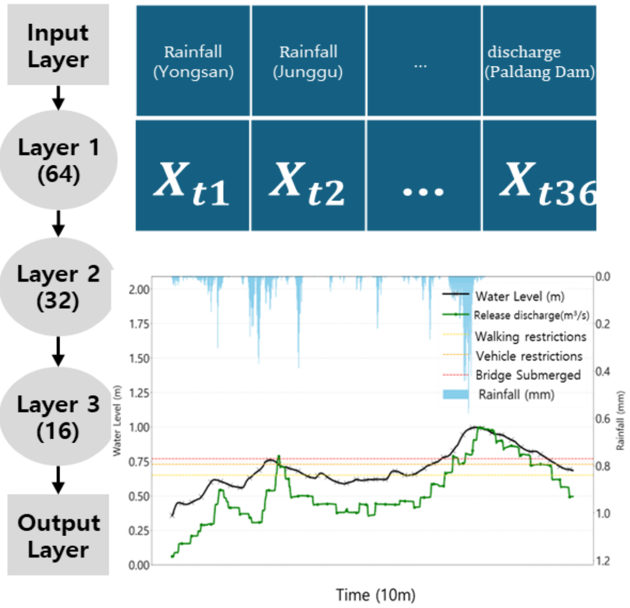
Build Model (LSTM)

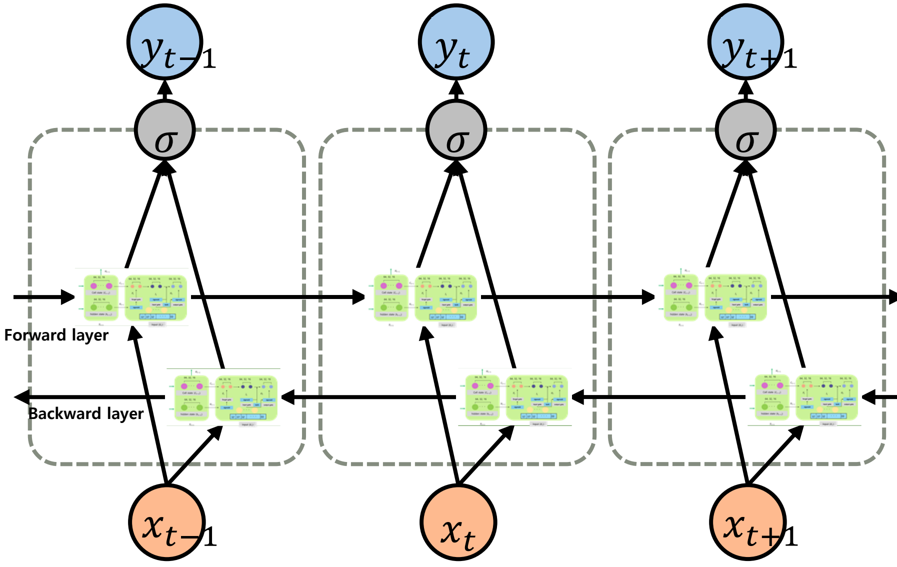
- Build a LSTM model with rainfall by weather station and Paldang dam discharge as input and jamsoo bridge water level as output.
- A total of 3 covert layers with 64, 32, and 16 nodes respectively

Build Model (Bi-LSTM)

- Build a Bi-LSTM model with rainfall and Paldang dam discharge by weather station as input and jamsoo bridge water level as output
- Build a Bi-LSTM model with the same structure as LSTM for comparison between models



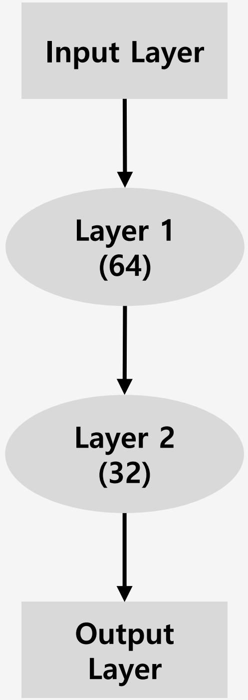


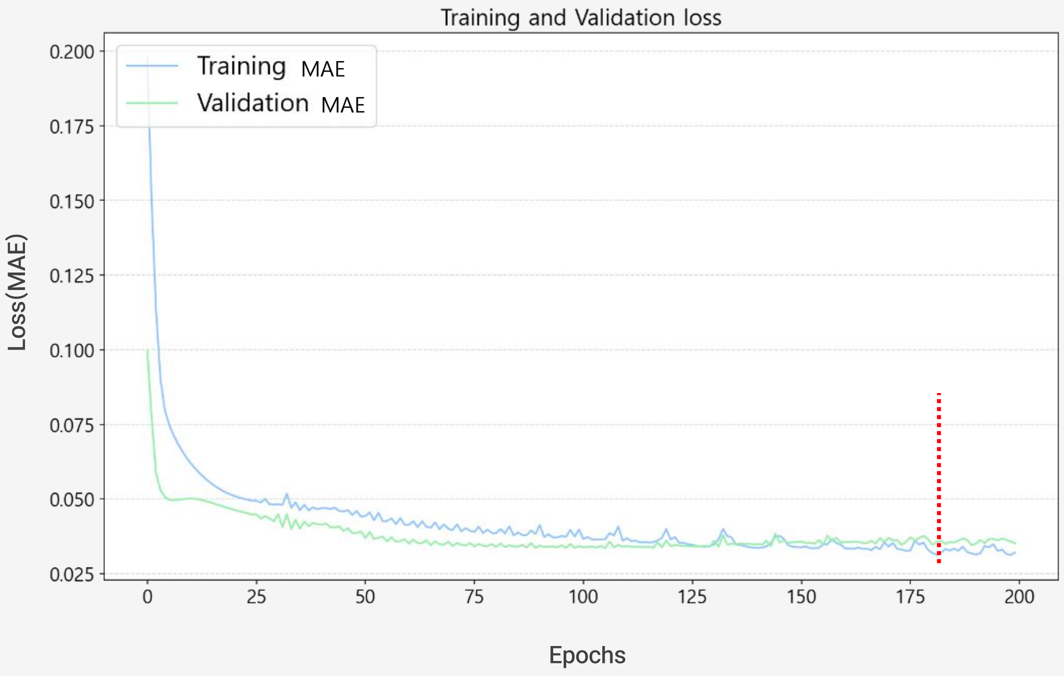


3.3 Build Model (LSTM)

- Out of 200 total runs, the 182th run had the lowest loss
- Building a Bi-LSTM model with 1 input layer, 2 hidden layers, and 1 output layer

LSTM (sequence : 36)					
Layer 1 (LSTM)		Layer 2 (LSTM)		Output Layer (Dense)	
units	64	units	32	units	16
activation	tanh	activation	tanh	activation	softplus
l2 regularizer	0.0001	l2 regularizer	0.0001		
Compile	epoch	200	loss	MSE	
	optimizer	Adam	learning rate	0.00004	

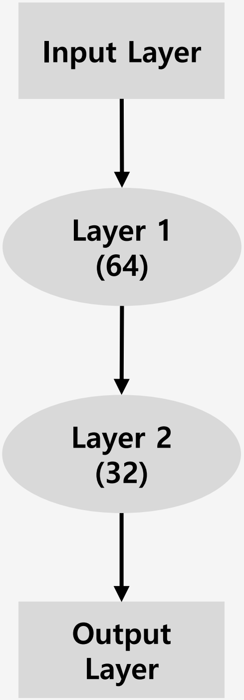


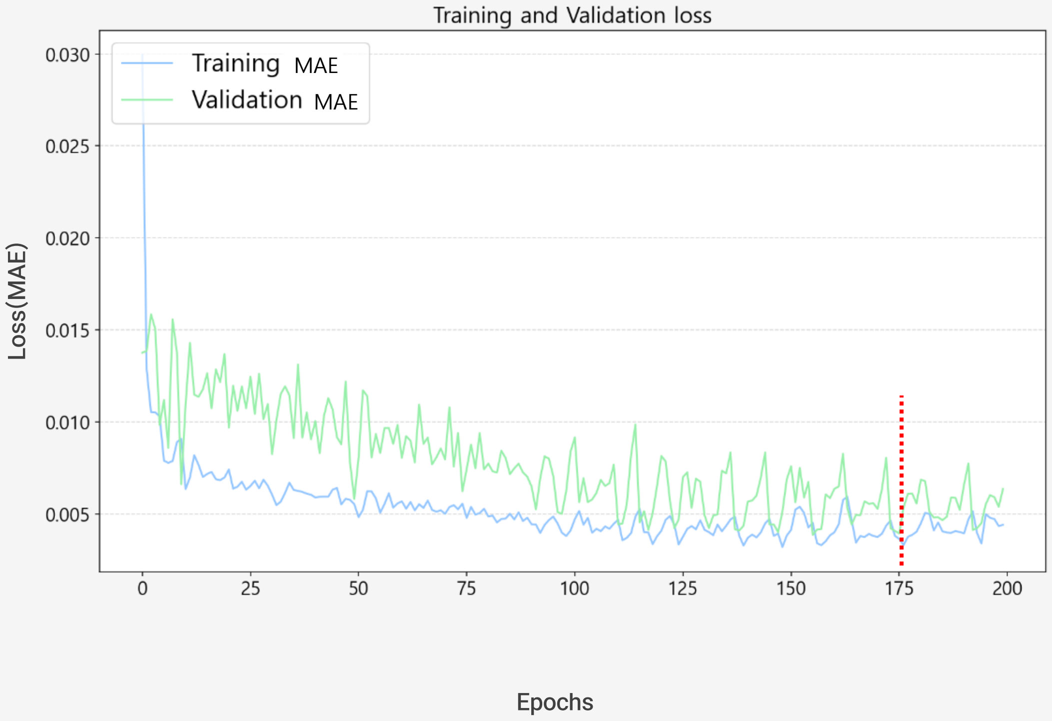


3.3 Build Model (Bi-LSTM)

- Out of 200 total runs, the 175th run had the lowest loss
- Building a Bi-LSTM model with 1 input layer, 2 hidden layers, and 1 output layer

Bi-LSTM (sequence : 36)					
Layer 1 (Bi-LSTM)		Layer 2 (Bi-LSTM)		Output Layer (Dense)	
units	64	units	32	units	16
activation	tanh	activation	tanh	activation	softplus
l2 regularizer	0.0001	l2 regularizer	0.0001		
Compile	epoch	200	loss	MSE	
	optimizer	Adam	learning rate	0.00004	





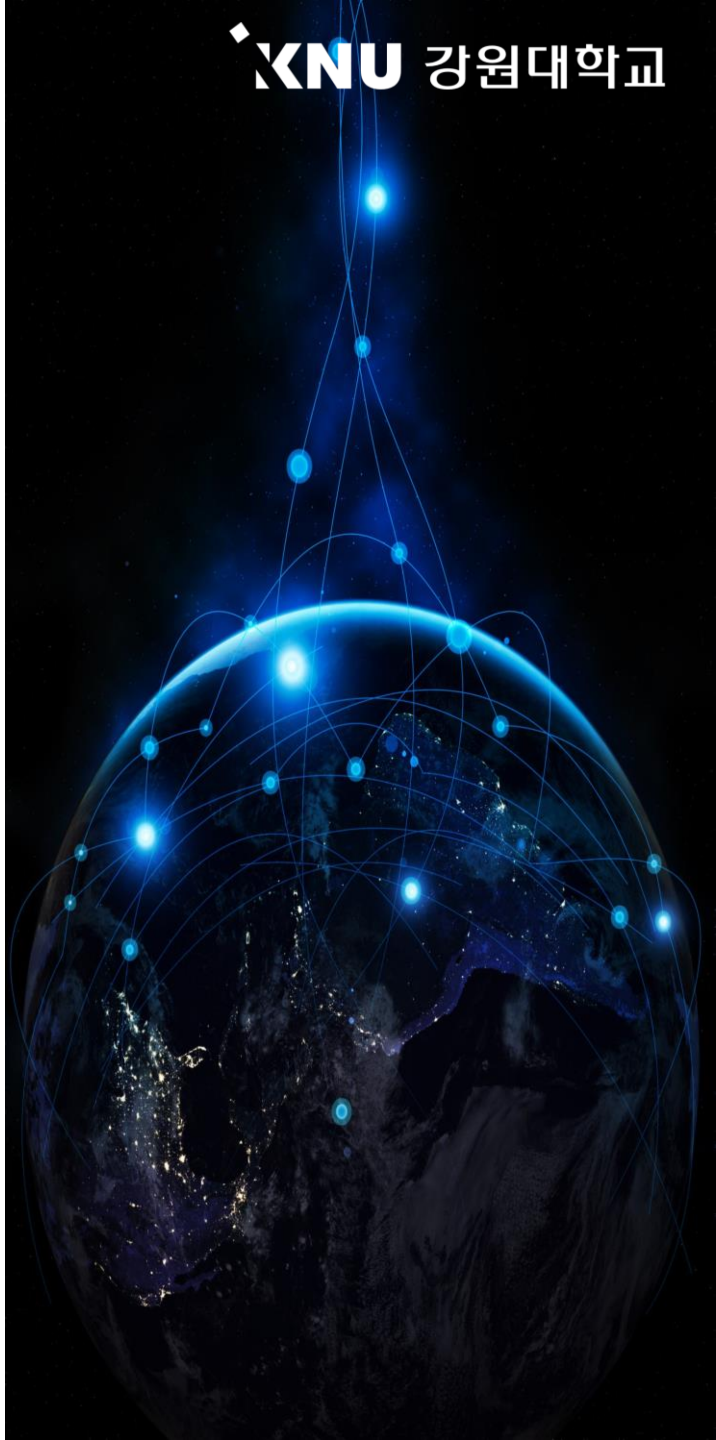
4. Results and Conclusions

4.1 Training Results

4.2 Test Results

4.3 Analysis Results

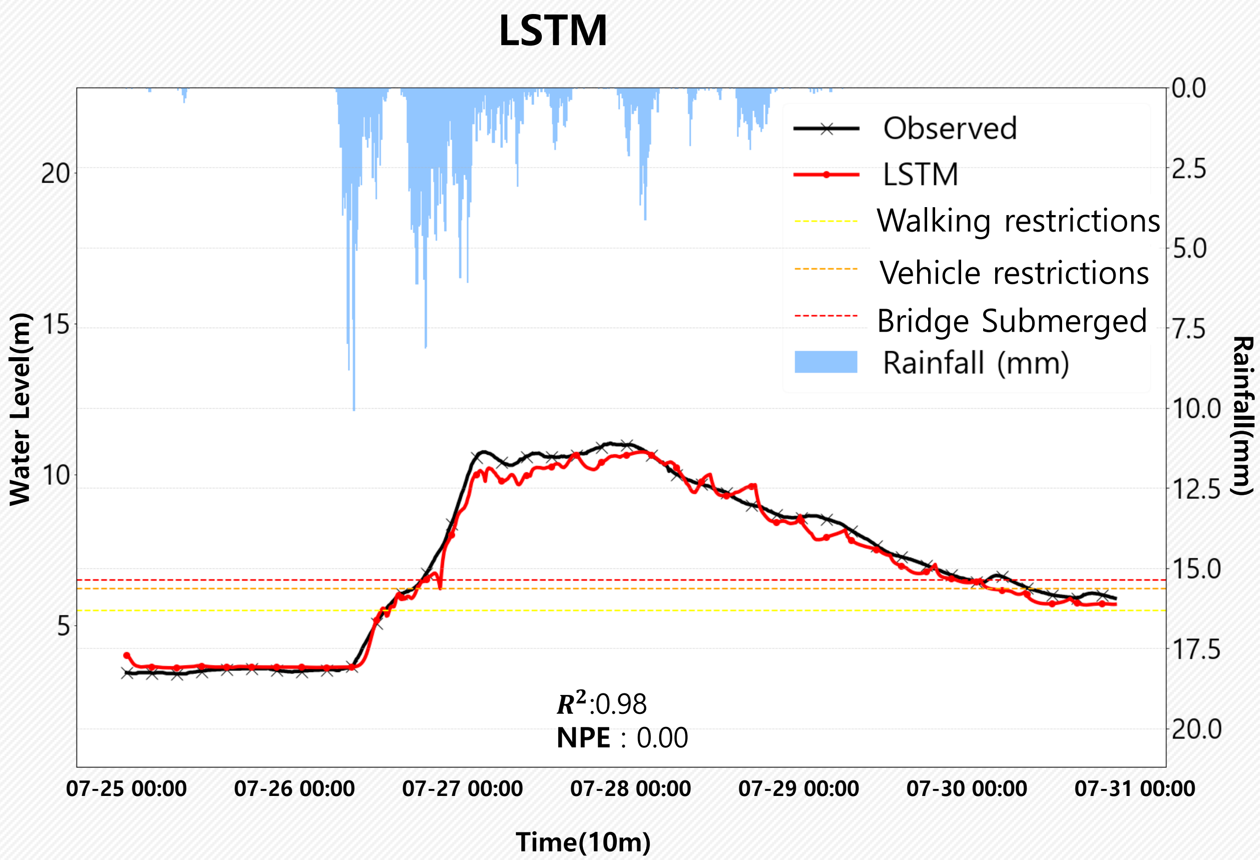
4.4 Conclusion

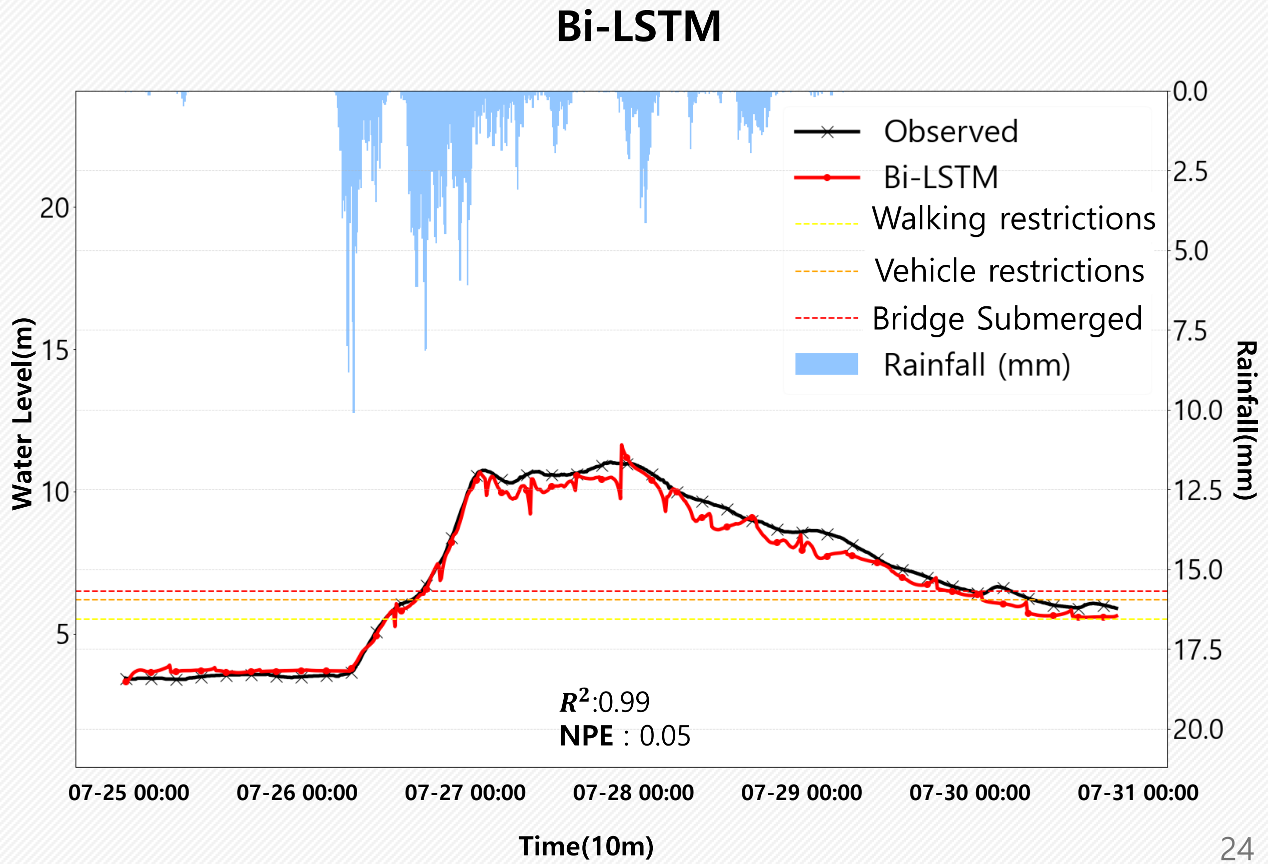


4.1 Results (Training)

- Five of the seven events were used as training data, and Event 6 and Event 7 were used as tests.
- The analysis data used the observed water level, rainfall, and dam discharge in 10-minute increments, and predicted 36 points in time (6 hours) with 828 points per event as input data.

Jamsoo Bridge Water Level Training Results (Event 1. July 2011 Heavy Rainfall 07.26~07.29)



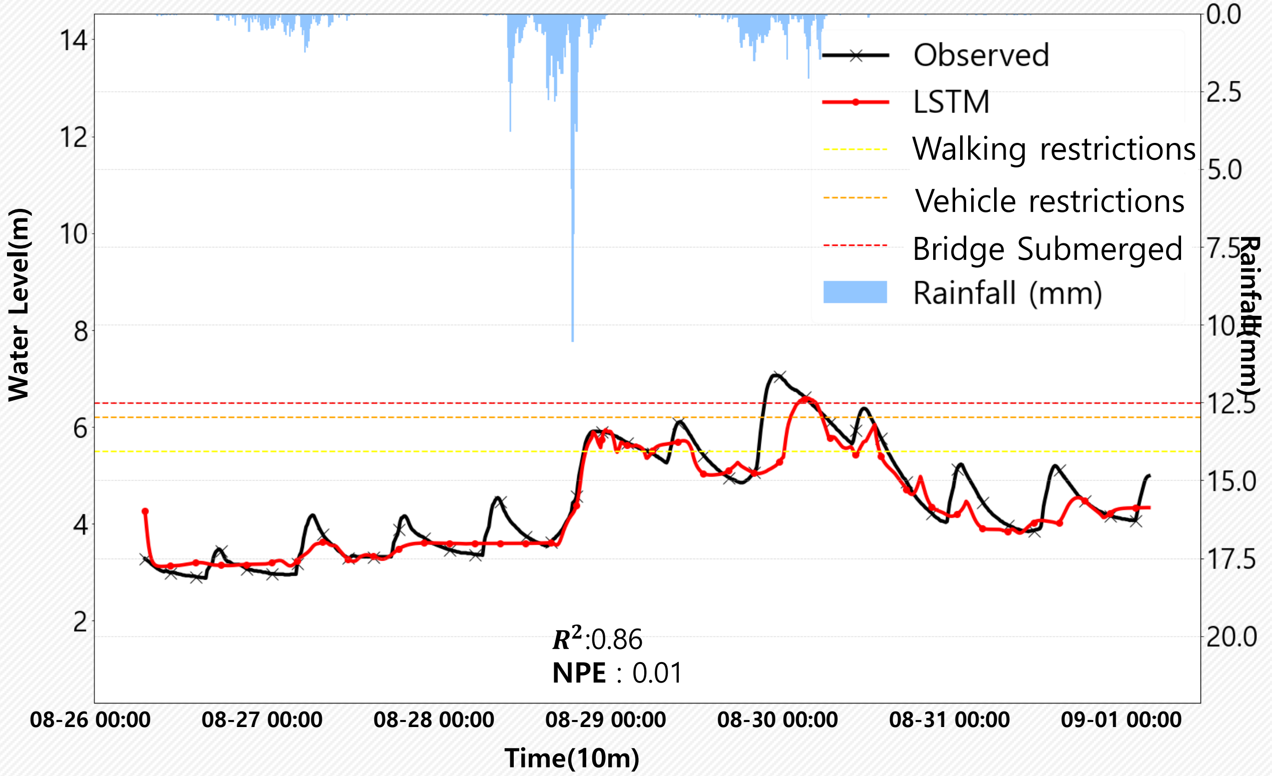


4.1 Results (Training)

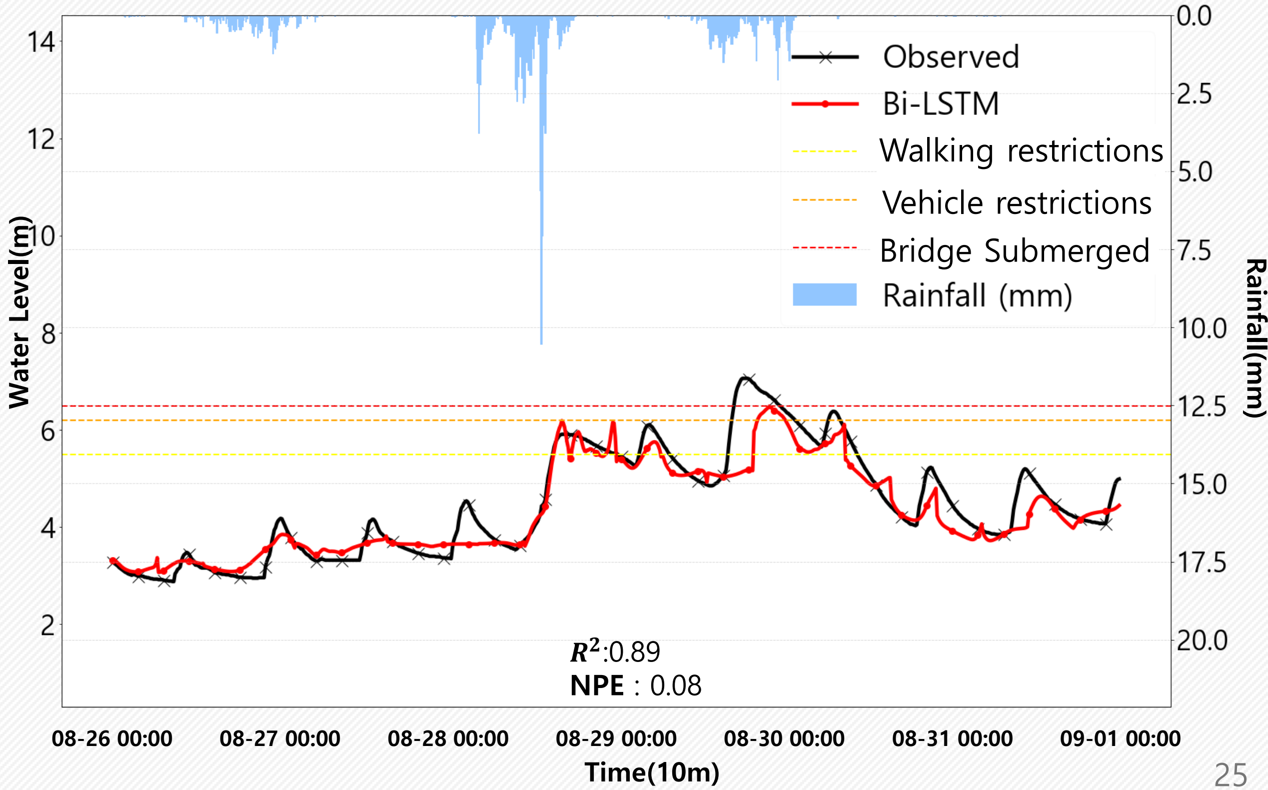
- Five of the seven events were used as training data, and Event 6 and Event 7 were used as tests.
- The analysis data used the observed water level, rainfall, and dam discharge in 10-minute increments, and predicted 36 points in time (6 hours) with 828 points per event as input data.

Jamsoo Bridge Water Level Training Results (Event 2. 2018 August Heavy Rainfall 08.26~09.01)

LSTM



Bi-LSTM

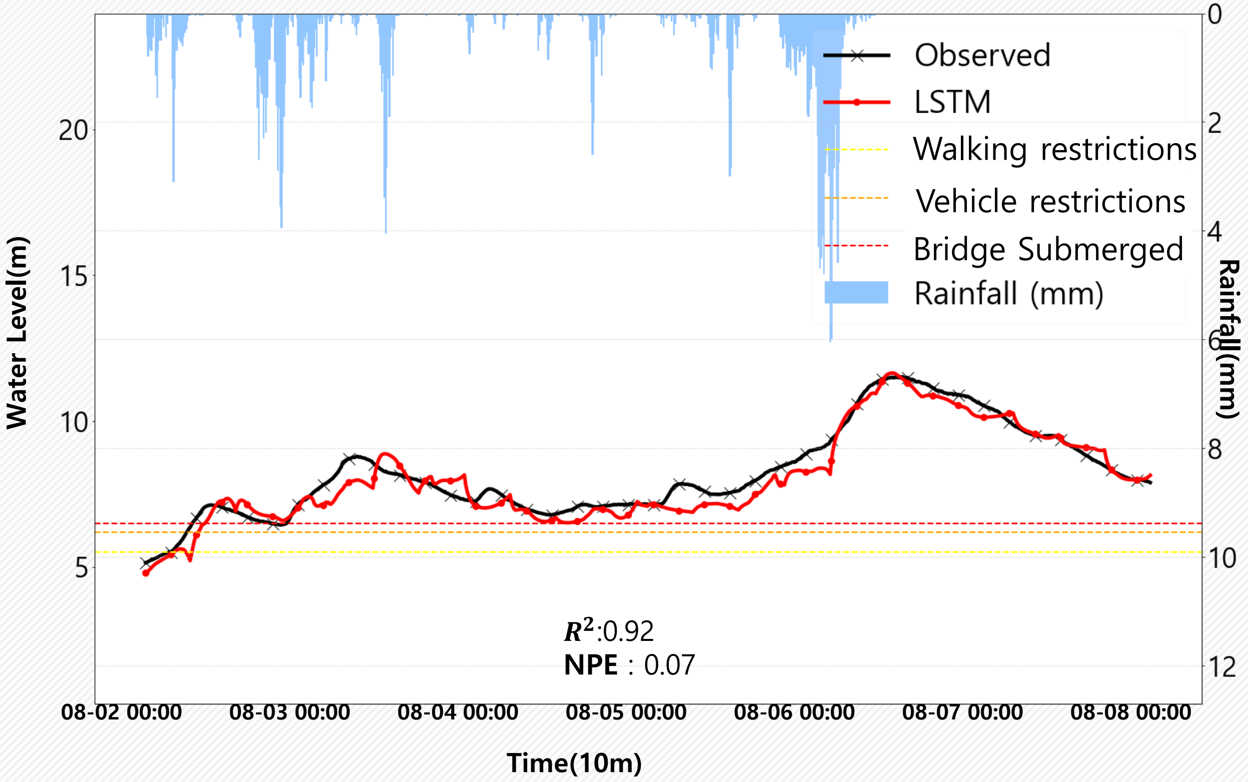


4.1 Results (Training)

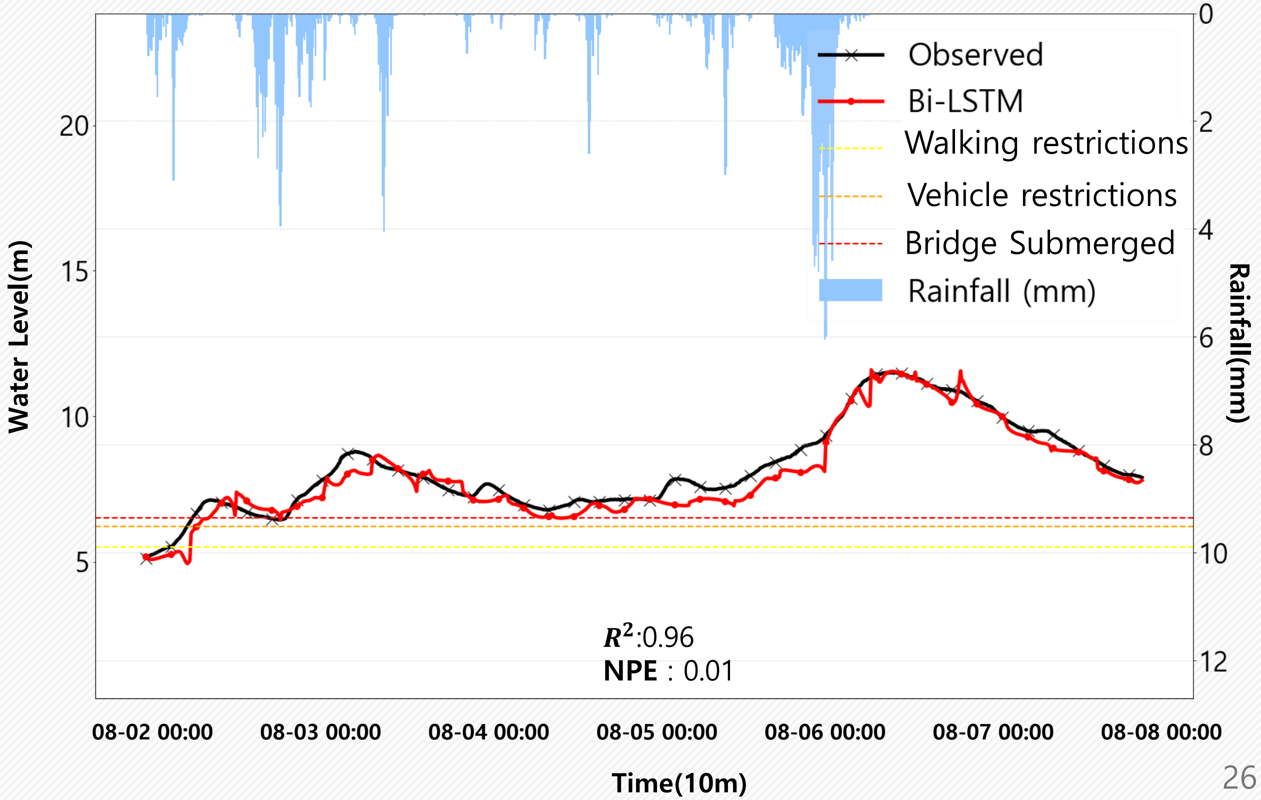
- Five of the seven events were used as training data, and Event 6 and Event 7 were used as tests.
- The analysis data used the observed water level, rainfall, and dam discharge in 10-minute increments, and predicted 36 points in time (6 hours) with 828 points per event as input data.

Jamsoo bridge water level training results (Event 3. August 2020 heavy rainfall 08.02~08.07)

LSTM



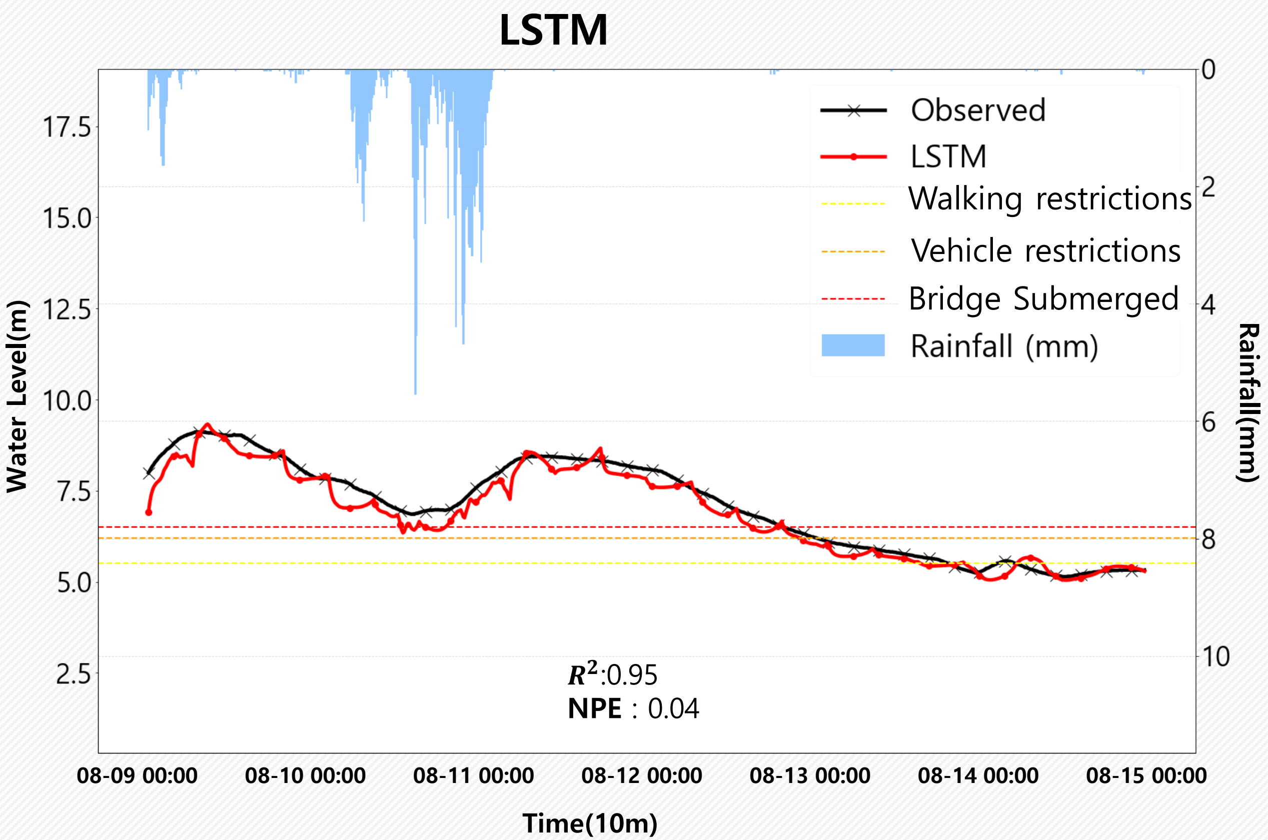
Bi-LSTM

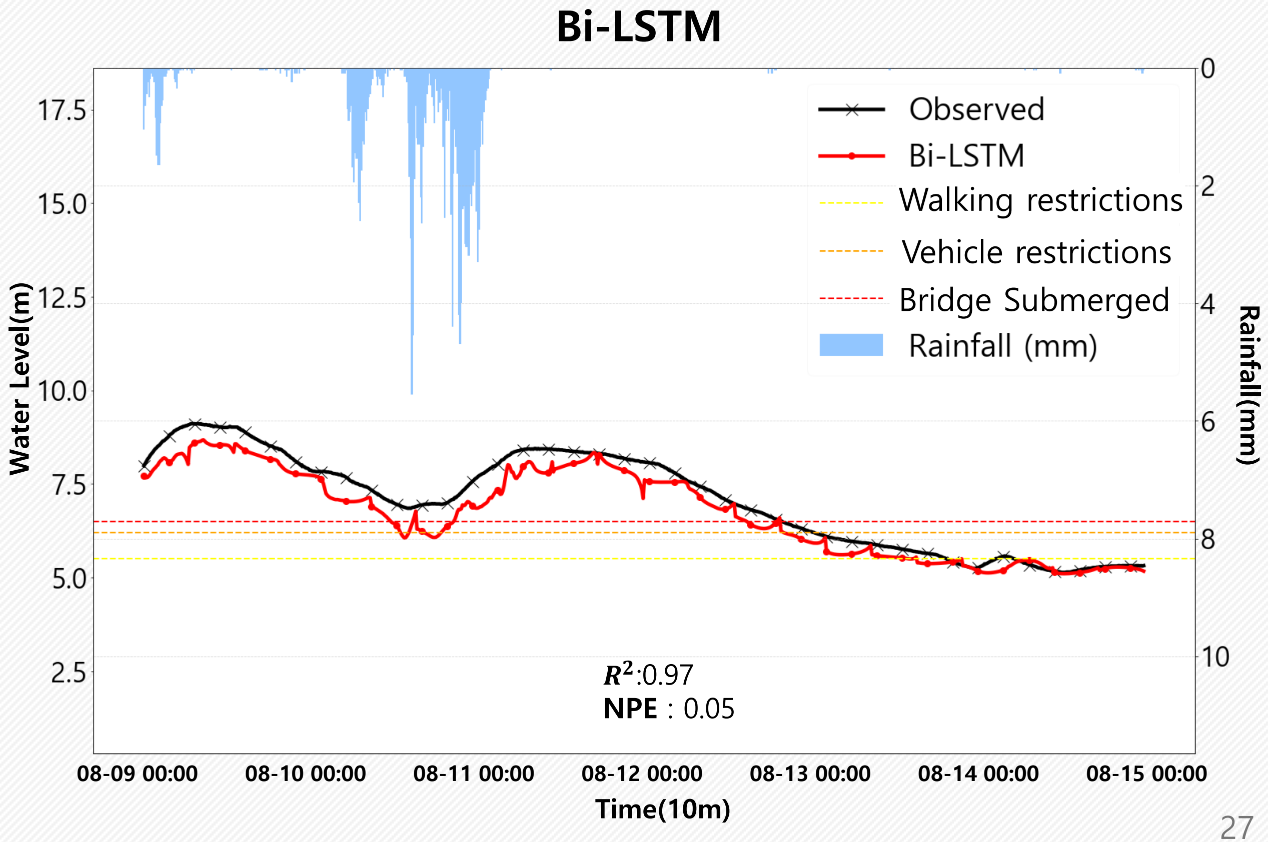


4.1 Results (Training)

- Five of the seven events were used as training data, and Event 6 and Event 7 were used as tests.
- The analysis data used the observed water level, rainfall, and dam discharge in 10-minute increments, and predicted 36 points in time (6 hours) with 828 points per event as input data.

Jamsoo bridge water level training results (Event 4. August 2020 heavy rainfall 08.09~08.14)

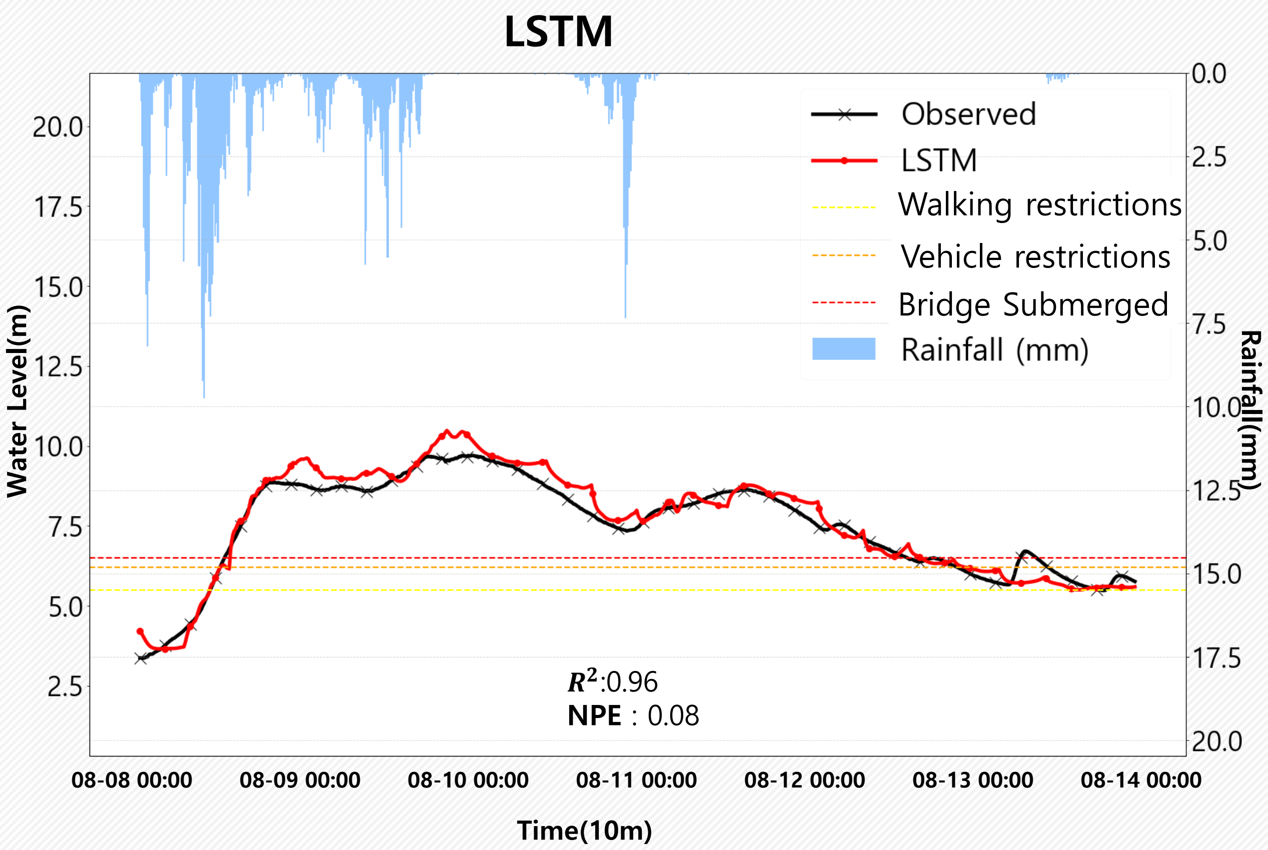


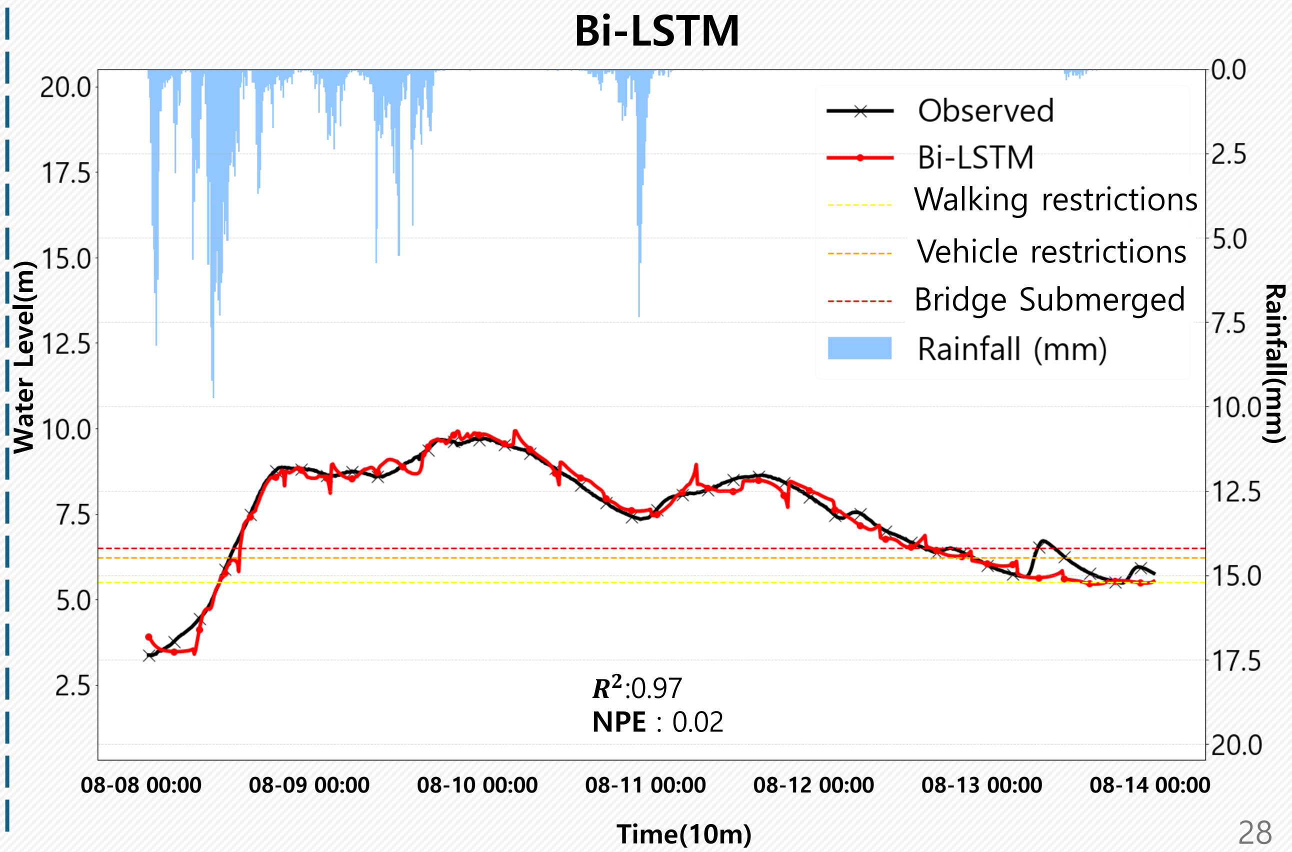


4.1 Results (Training)

- Five of the seven events were used as training data, and Event 6 and Event 7 were used as tests.
- The analysis data used the observed water level, rainfall, and dam discharge in 10-minute increments, and predicted 36 points in time (6 hours) with 828 points per event as input data.

Jamsoo bridge water level training results (Event 5. August 2022 heavy rainfall 08.08~08.17)

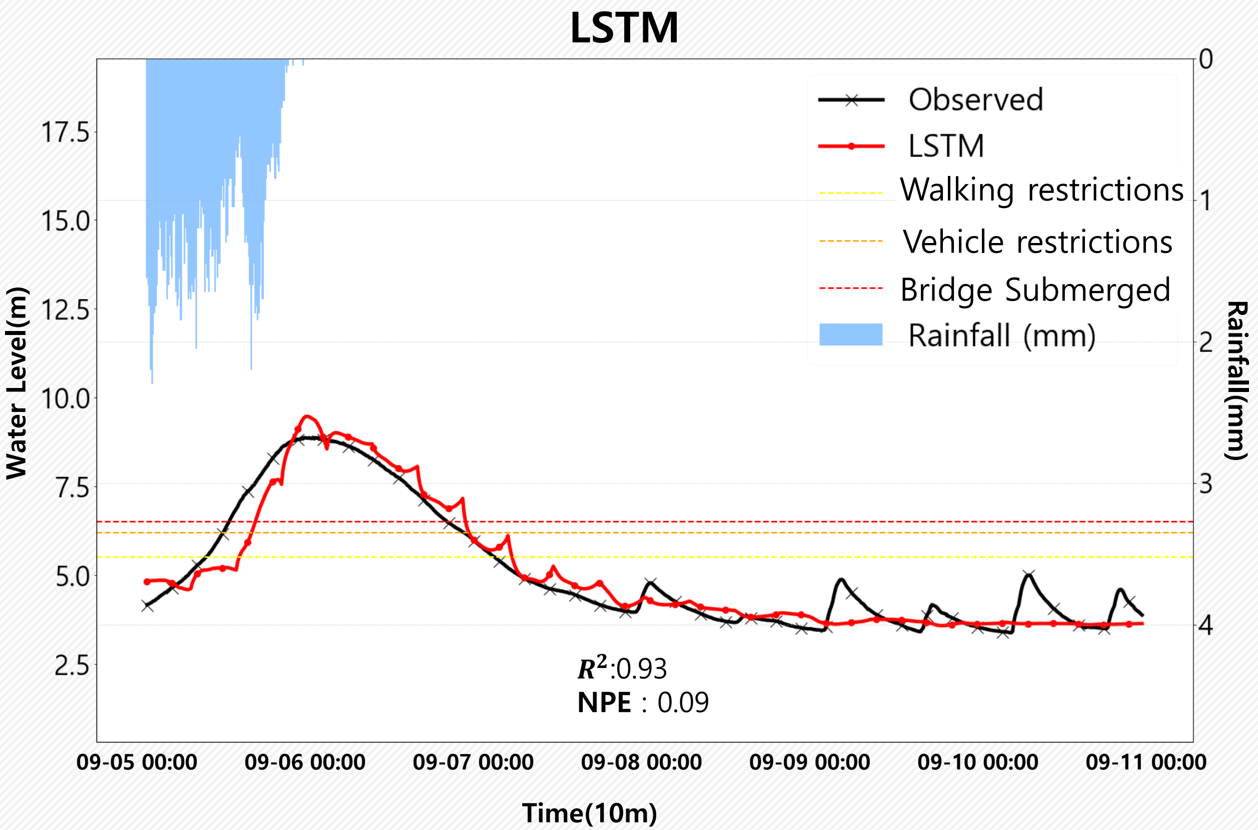


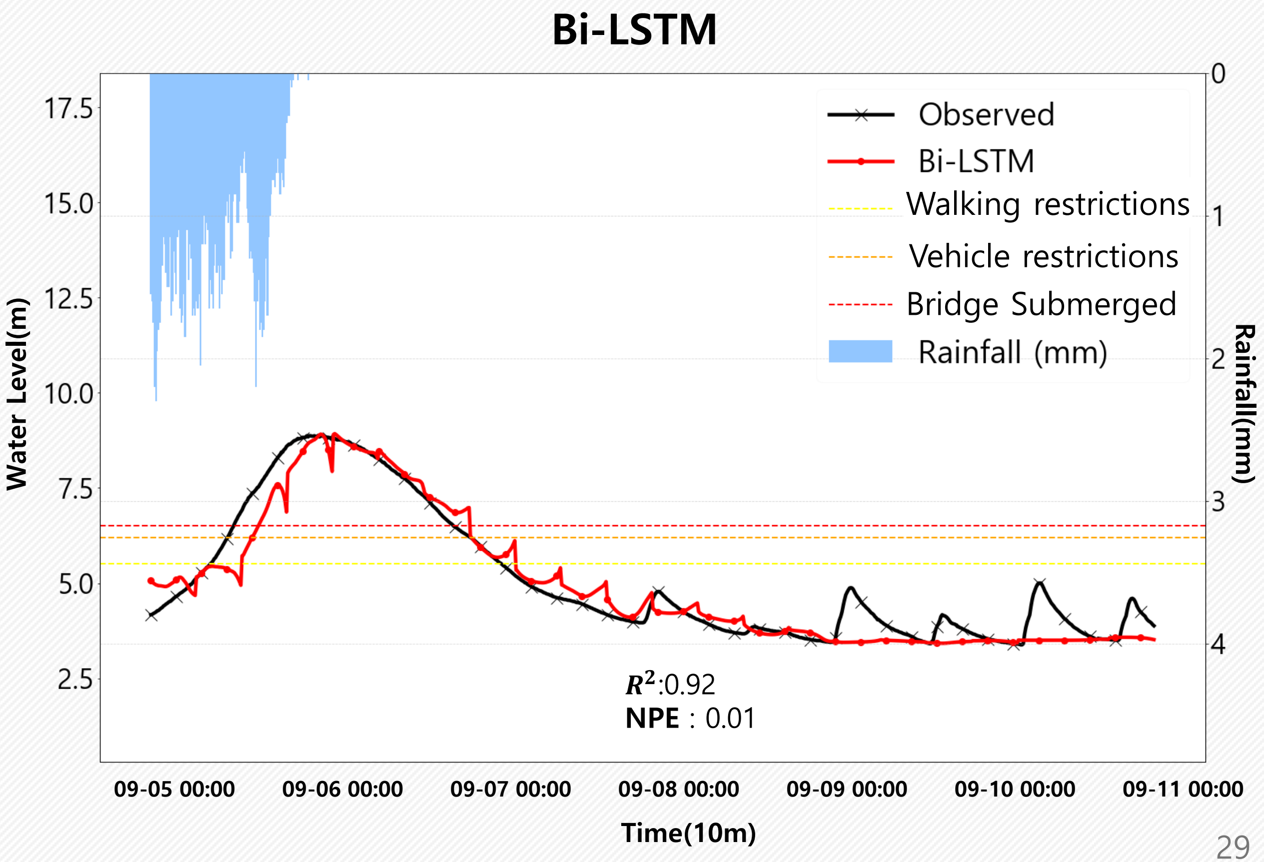


4.2 Results (Test)

- Five of the seven events were used as training data, and Event 6 and Event 7 were used as tests.
- The analysis data used the observed water level, rainfall, and dam discharge in 10-minute increments, and predicted 36 points in time (6 hours) with 828 points per event as input data.

Jamsoo Bridge Water Level Test Results (Event 6, 2022 Typhoon "Hinnamno" 08.28~09.06)



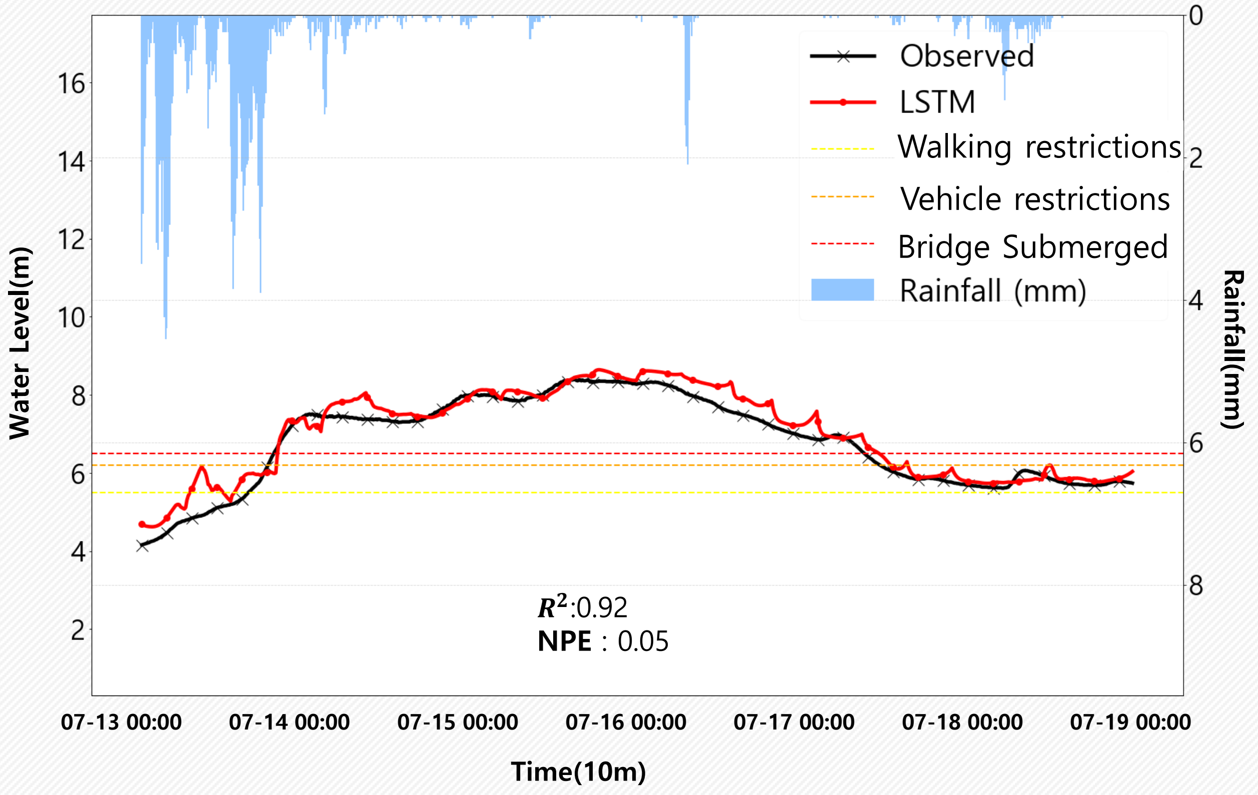


4.2 Results (Test)

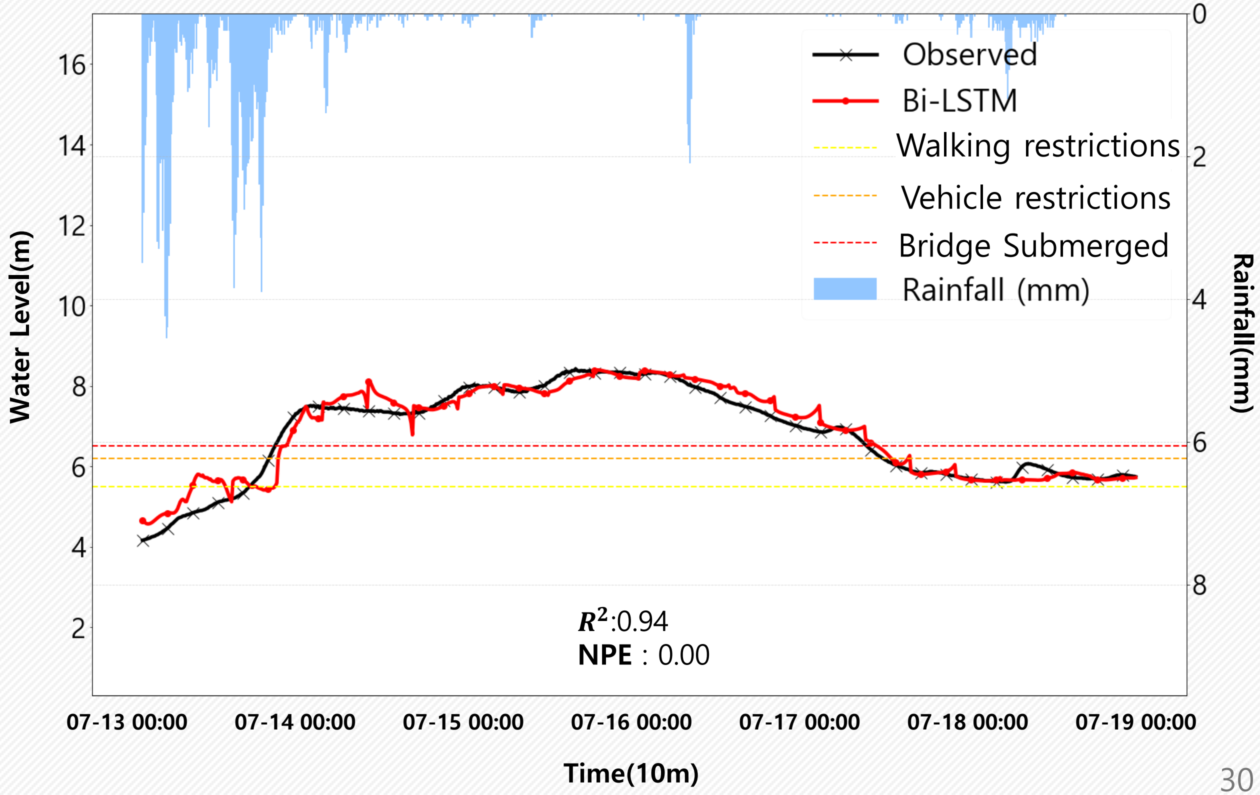
- Five of the seven events were used as training data, and Event 6 and Event 7 were used as tests.
- The analysis data used the observed water level, rainfall, and dam discharge in 10-minute increments, and predicted 36 points in time (6 hours) with 828 points per event as input data.

Jamsoo bridge water level test result (Event 7. July 2023 heavy rainfall 07.13~07.18)

LSTM



Bi-LSTM



4.3 Results (Training)

- After training the models, the overall error and accuracy of LSTM and Bi-LSTM were similar, with Bi-LSTM having a PBIAS of -2.85, which is 2.82 higher than LSTM.

LSTM Evaluation metric

Event	ME	MAE	MSE	RMSE	NPE	NSE	R2	KGE	PBiAS (%)
Event 1	-0.1	0.26	0.13	0.37	0	0.98	0.98	0.97	-1.42
Event 2	-0.05	0.29	0.18	0.42	0.01	0.85	0.86	0.92	-1.17
Event 3	0.02	0.37	0.21	0.46	0.07	0.91	0.92	0.94	0.28
Event 4	-0.09	0.21	0.09	0.3	0.04	0.95	0.95	0.94	-1.26
Event 5	0.25	0.37	0.19	0.44	0.08	0.92	0.96	0.90	3.41
Avg	**0.01**	**0.30**	**0.16**	**0.40**	**0.04**	**0.92**	**0.93**	**0.93**	**-0.03**

Bi-LSTM Evaluation metric

Event	ME	MAE	MSE	RMSE	NPE	NSE	R2	KGE	PBiAS (%)
Event 1	-0.21	0.31	0.14	0.37	0.05	0.98	0.99	0.92	-2.92
Event 2	-0.13	0.26	0.16	0.4	0.08	0.87	0.89	0.83	-2.87
Event 3	-0.23	0.32	0.16	0.4	0.01	0.93	0.96	0.95	-2.84
Event 4	-0.34	0.35	0.17	0.41	0.05	0.89	0.97	0.89	-4.86
Event 5	-0.06	0.21	0.08	0.28	0.02	0.97	0.97	0.93	-0.75
Avg	**-0.194**	**0.29**	**0.14**	**0.37**	**0.04**	**0.93**	**0.96**	**0.90**	**-2.85**

4.3 Analysis(Test)

- The average errors for Events 1-7 are all larger for LSTM than Bi-LSTM
- All metrics for accuracy are higher for Bi-LSTM than LSTM
- Overall, the Bi-LSTM has a lower error and higher accuracy, indicating that the Bi-LSTM model performs better in predicting the water level of the jamsoo bridge.

LSTM Evaluation metric

Event	ME	MAE	MSE	RMSE	NPE	NSE	R2	VE	KGE	PBiAS (%)
Event 6	0.2	0.45	0.26	0.51	0.09	0.91	0.93	0.68	0.93	-1.42
Event 7	0.39	0.41	0.26	0.51	0.05	0.8	0.92	0.59	0.93	-1.17
Avg	**0.30**	**0.43**	**0.26**	**0.51**	**0.07**	**0.86**	**0.93**	**0.64**	**0.93**	**-1.30**

Bi-LSTM Evaluation metric

Event	ME	MAE	MSE	RMSE	NPE	NSE	R2	VE	KGE	PBiAS (%)
Event 6	-0.13	0.36	0.26	0.51	0.01	0.91	0.92	0.75	0.95	-2.46
Event 7	0.07	0.21	0.08	0.28	0	0.94	0.94	0.79	0.96	1.06
Avg	**-0.03**	**0.29**	**0.17**	**0.40**	**0.01**	**0.93**	**0.93**	**0.77**	**0.96**	**-0.70**

4.5 Conclusion

- To develop a water level prediction model for the hangang river Jamsoo bridge, we used 10-minute rainfall data and paldang dam discharge data to predict the 6-hour water level of the jamsoo(submerged) bridge.

- Used a total of 7 rainfall evensts, July 2011, august 2018, august 2020, and august 2022 (09~14) were used for training, and august 2022 (28~09.06) and august 2023 were used for testing.

- In model training, LSTM showed lower error and higher accuracy overall, and PBIAS was 2.82 higher than LSTM with Bi-LSTM at -2.85.
- In model test, event 6 and 7, the LSTM has higher error and lower accuracy, while the Bi-LSTM outperforms.
- In the test, the Bi-LSTM has a smaller error and higher accuracy, indicating that the Bi-LSTM model is better at predicting the water level of the jamsoo bridge.

- The Bi-LSTM model performed well in predicting the water level of the hangang river jamsoo bridge, so it is expected to be highly utilized at other points other than the hangnag river jamsoo bridge and can be used for real-time flood prediction and safety operation.

Development of Flood Level Prediction Model for Hangang River Jamsoo Bridge Using Weather Climate Data and Artificial Neural Networks

Master's course at Kangwon National University

Sung Chul, HA

2025. 03. 18

scsc0325@kangwon.ac.kr

KNU

AI 기후재난기술융합연구소
AI for Climate & Disaster Management Center