

Hydro-Barrier Flood Protector with Rain Drainage And Traffic Regulator Smart Systems for Underpass

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Introduction

Problem Statement:

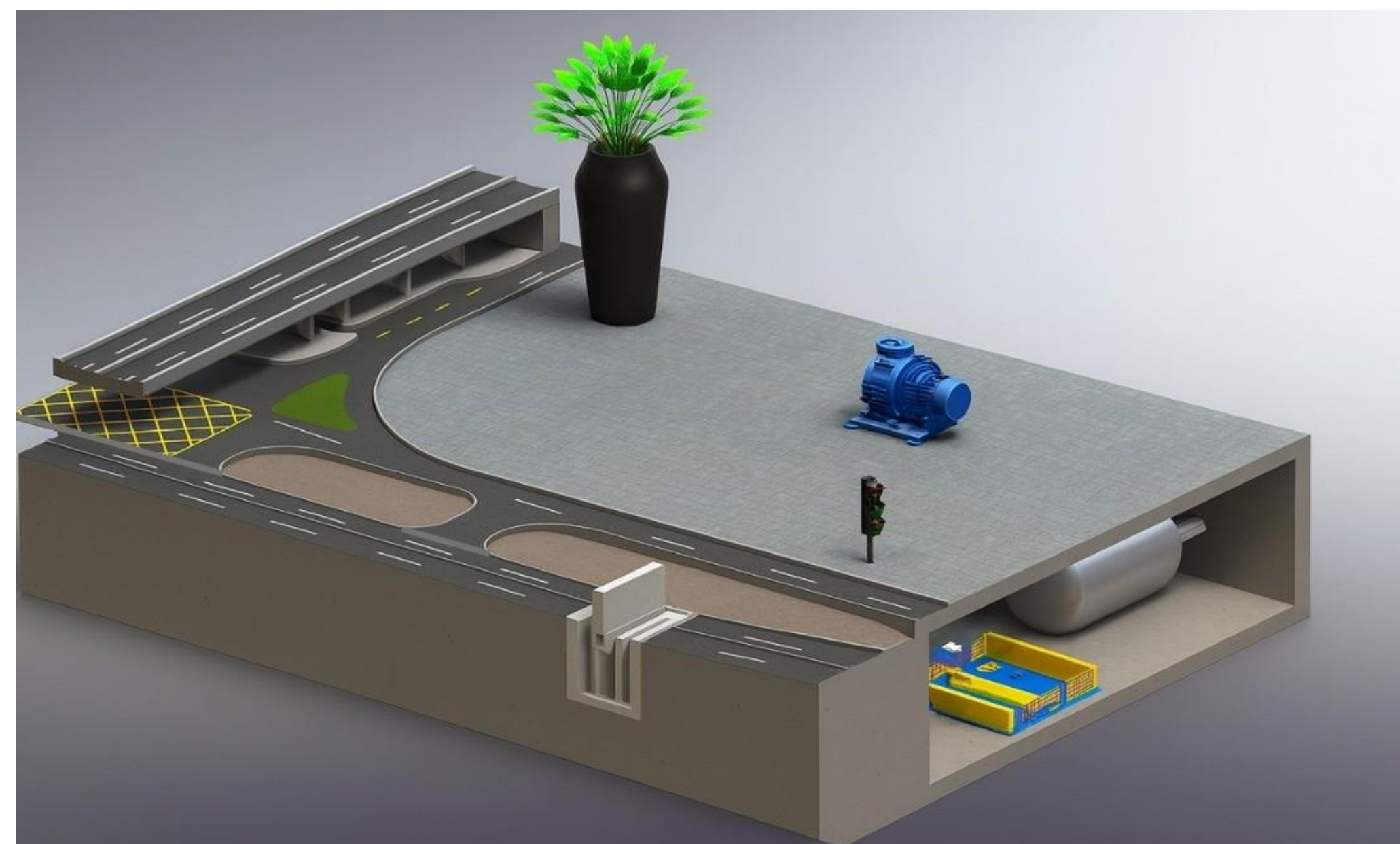
Heavy rainfall in Saudi Arabia causes recurring flooding in tunnels, underground parking, and other water-accumulation areas, as seen in the 2011 Jeddah flood with losses of approximately 17 billion SAR. Current systems lack real-time monitoring, automated warnings, and rainwater treatment, leading to preventable safety risks and wasted resources.

Objective:

To develop an integrated system that prevents drivers from entering flooded areas through real-time detection and automated warnings, while redirecting and filtering rainwater for reuse in irrigation and urban greening in support of Vision 2030.

Constraints	Specifications
Development cost < 8,000 SAR	Internal storage capacity > 2 L
Flush with ground (< 2 cm)	External storage capacity > 3 L
Validated via simulation.	Blade angle 15°–50° to optimize flow

Prototype Design

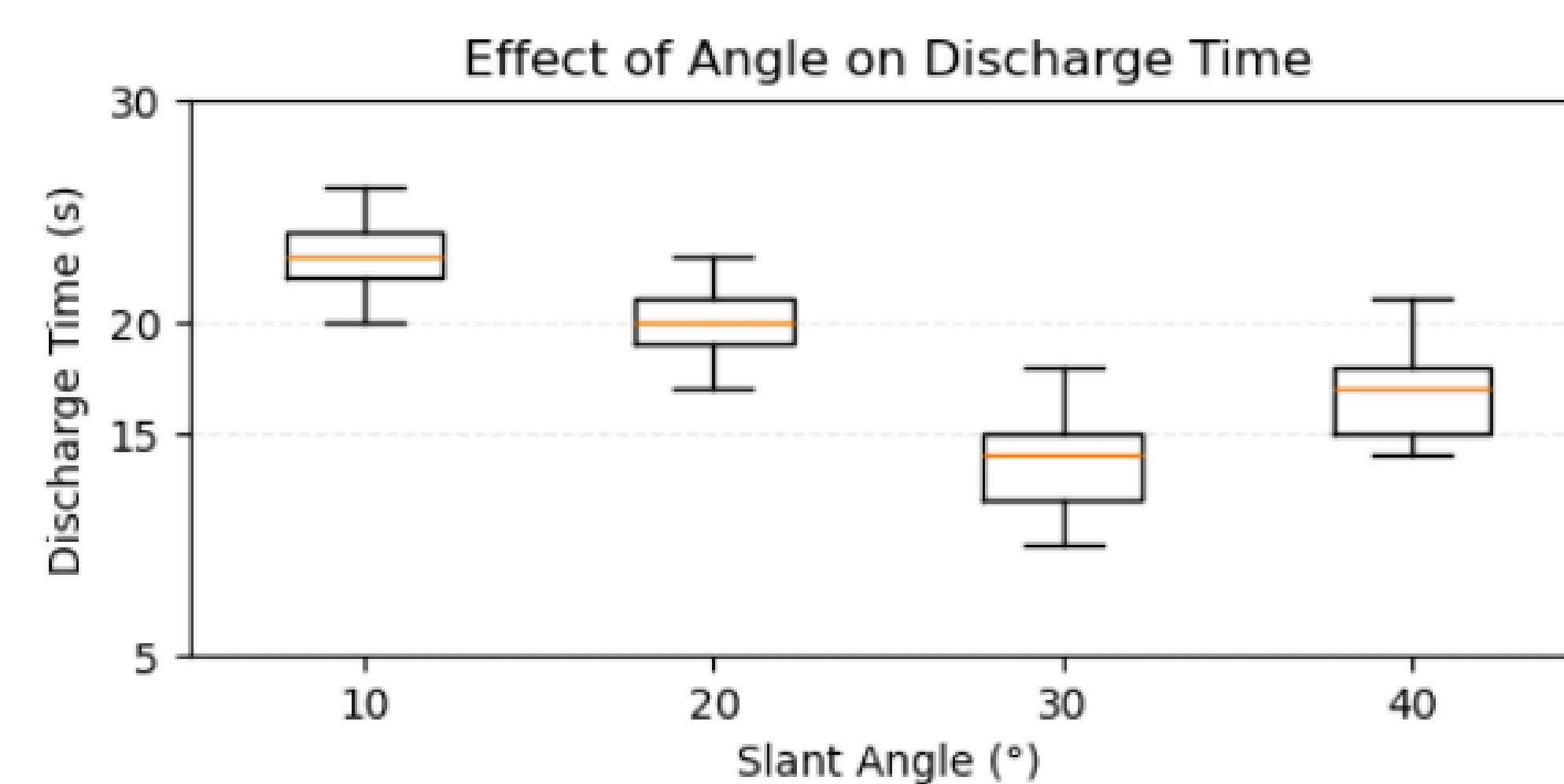


Testing/ Validation

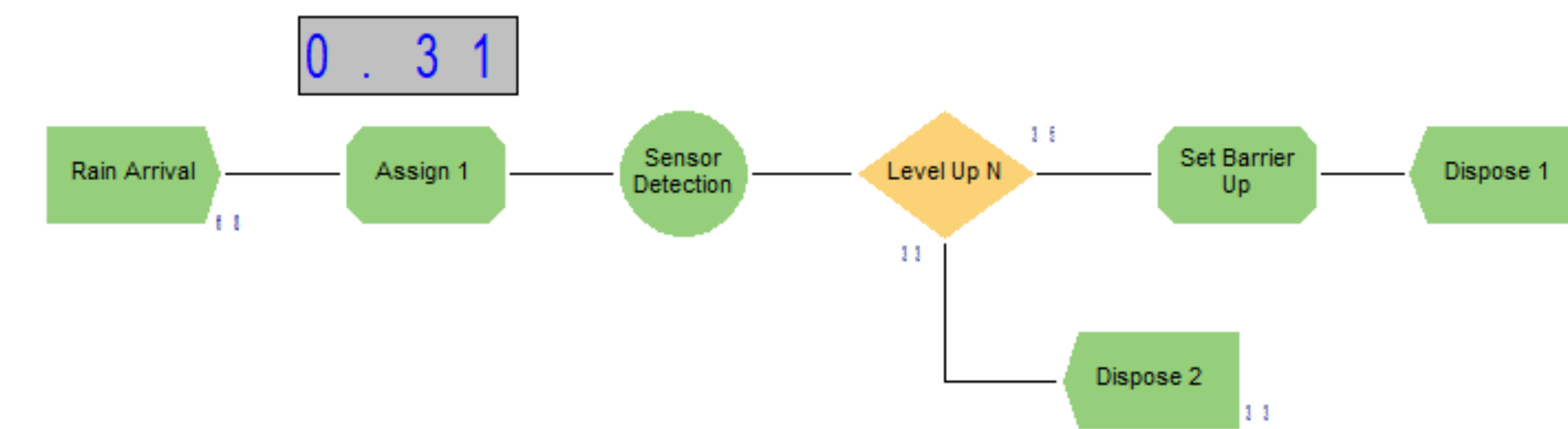
ANOVA Results for Discharge Time

ANOVA Table	SS	DF	MS	F0	PV
Angle	903.667	3.0	301.2223	231.0395	0.000
Slot Width	116.258	1.0	116.2584	89.1710	0.000
Slot Spacing	131.430	1.0	131.4306	100.8082	0.000
Angle: SW	1.715	3.0	0.5717	0.4385	0.726
Angle: SS	6.146	3.0	2.0487	1.5713	0.205
SW : SS	3.561	1.0	3.5617	2.7318	0.103
Angle: SW: SS	3.200	3.0	1.0667	0.8181	0.488
Residual	83.441	64.0	1.3038	NaN	NaN

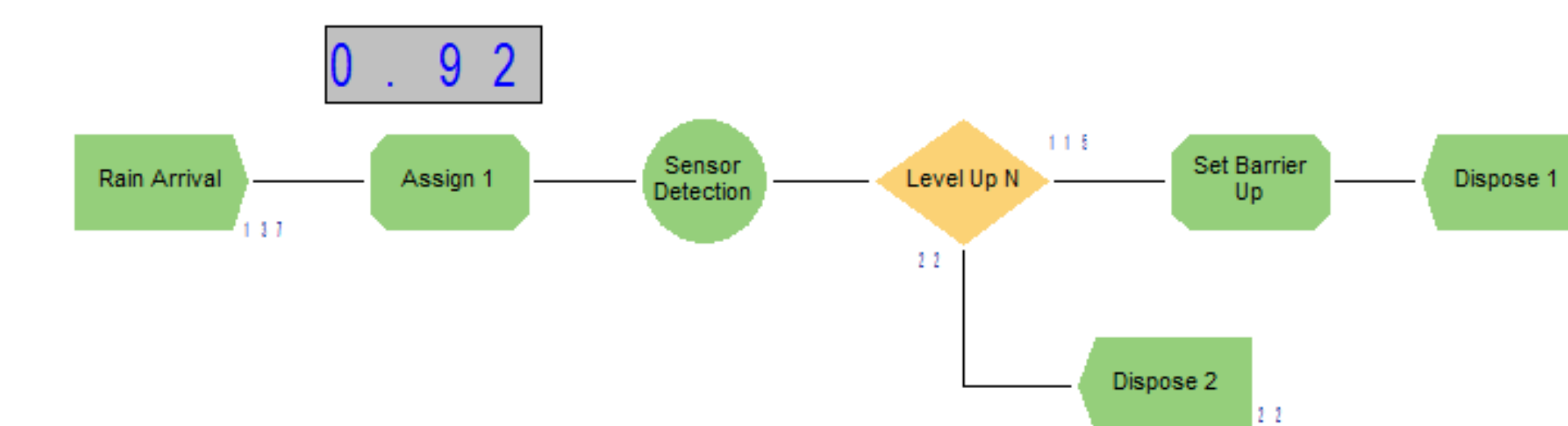
Boxplot of Slant Angles



Normal Rainfall Simulation Model

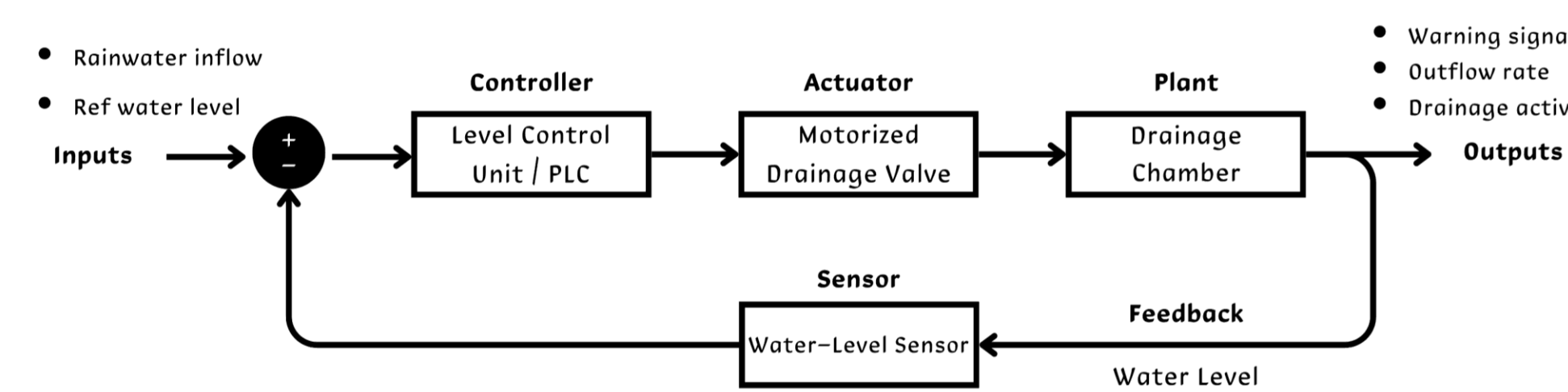


Heavy Rainfall Simulation Model



Warning System

Block Diagram:

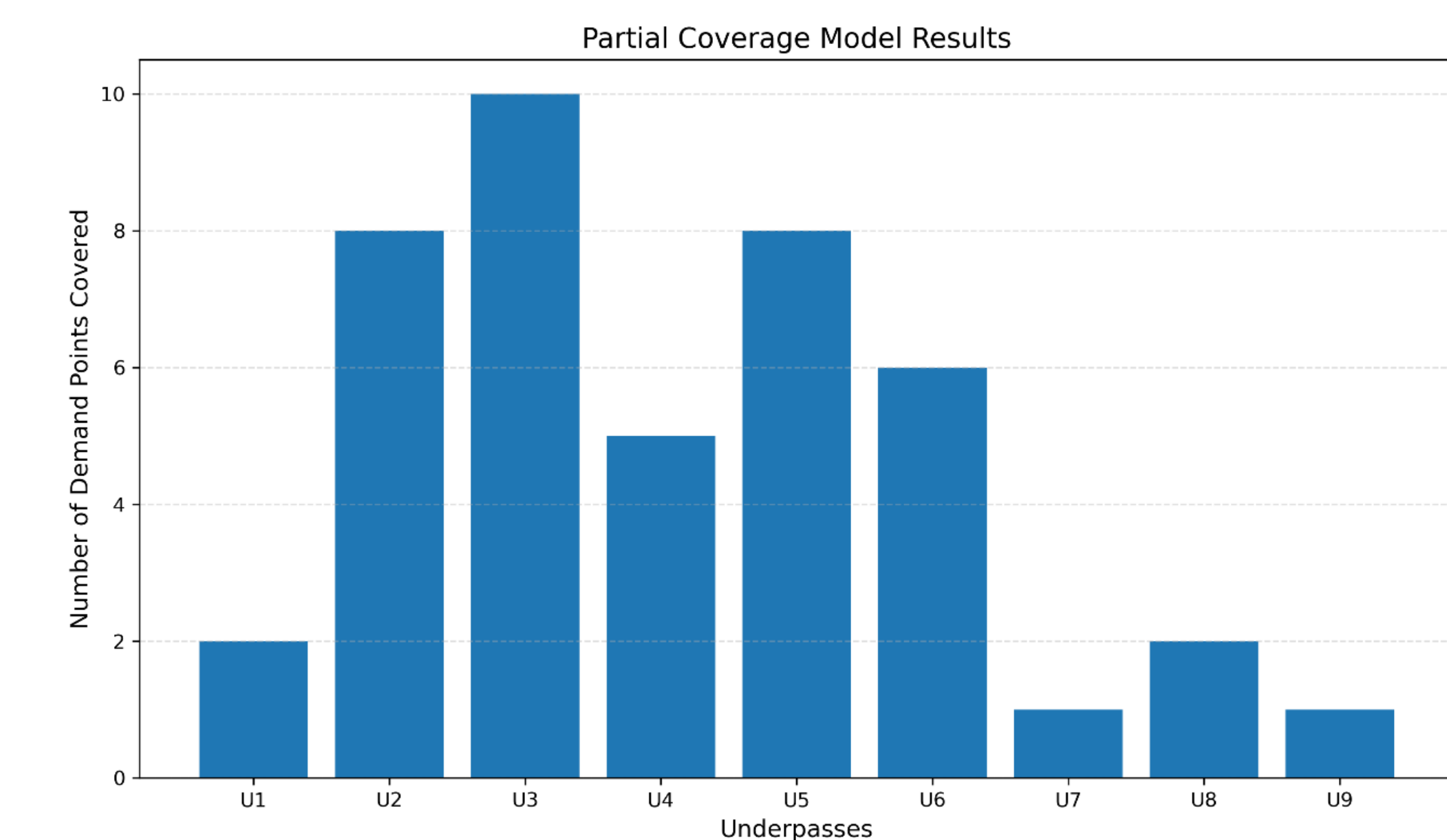


Information Theory:

Warning state	(p _i)	(h _i = log ₂ 1/p _i)	Human-factors note
Green	0.788	0.34 bits	Very common, carries little information
Orange	0.121	3.05 bits	Less frequent, moderate informative
Orange-Flashing	0.074	3.76 bits	Rare; highly informative,
Red	0.017	5.88 bits	Extremely rare; maximally informative,

Site Selection

Partial Covering:



U3 (Prince Naif Underpass), among all Dammam underpasses, achieved the highest coverage, serving the largest cluster of public facilities and critical demand points.



Conclusion

HydroGuard is an automated, energy-independent system driven by buoyant force. Designed to remain flush with the road for safety, it offers triple protection—blocking, redirecting, and storing floodwater—to secure underpasses against submersion.