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Evaluation and Redesign of a Retention Pond for Flood Control in the Perumahan Irigasi Danita in East Bekasi

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Abstract: Urban drainage infrastructure consists of minor systems, such as drainage channels, and major systems, such as retention/detention basins and receiving water bodies. The city of Bekasi, as part of the Jabodetabek metropolitan area, is prone to flooding due to high rates of land conversion and the shrinking of green open spaces. Data from the Bekasi City Disaster Management Agency (BPBD) shows an increase in flood-prone areas from 20 locations across 7 subdistricts in March 2025 to 28 locations in January 2026, with the Danita Irrigation Housing Complex in East Bekasi being a consistently affected area. Current conditions show sediment buildup in drainage channels ranging from 5 to 40 cm and a reduction in retention pond capacity due to sediment deposits 2.71 m thick. Topographically, this area is situated at an elevation of 11–18 meters above sea level and has a bowl-shaped topography, which causes water flow to concentrate at a single point, thereby exacerbating the potential for flooding. This study aims to evaluate the performance of the existing drainage system and redesign the retention pond through hydrological analysis of design rainfall events and EPA SWMM 5.2 simulations. Simulations of existing conditions yielded a flood volume of 3.525×10^6 liters, indicating that the system's capacity is inadequate. The retention pond was redesigned with a minimum capacity of 2,863 m^3 and a design capacity of ±4,300 m^3 using a safety factor of 1.5, with a pond depth of 5 m, resulting in a planned pond area of 860 m^2. The results of the post-redesign simulation show that the basin is capable of reducing flooding by up to 100% within the basin area, with a remaining storage capacity of approximately 50% of the design flood volume; thus, the system is deemed feasible and has adequate resilience against extreme rainfall events. The estimated construction cost for the redesign of the retention basin is Rp1,119,315,000.00.

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1. Introduction

The rapid pace of urbanization in urban areas is driving a shift in land use from open spaces to built-up areas, which in turn impacts urban water management [1]. The expansion of impervious surfaces resulting from this process hinders infiltration into the soil, causing a significant increase in the volume of water entering drainage systems in the form of surface runoff [2]. In the context of urban drainage management, flood control systems are categorized into "minor systems"—comprising drainage channel networks—and "major systems," which include storage infrastructure such as retention/detention basins and receiving water bodies [3]. If the capacity of the minor system is insufficient to accommodate the volume of runoff during heavy rainfall, the entire flow load will be transferred to the major system. If the capacity of the main drainage system is insufficient, rainwater cannot be drained efficiently, leading to puddles and localized flooding in urban areas.

Data from the Bekasi City Disaster Management Agency (BPBD) shows an upward trend in flooding incidents, rising from 20 locations across 7 subdistricts on March 4, 2025, to 28 locations on January 29, 2026, with the Danita Irrigation Housing Complex in East Bekasi consistently listed as an affected area. On May 13, 2025, RW 14 in the Danita Irrigation Housing Complex experienced flooding with water levels ranging from 5 to 20 cm, requiring the operation of pumps to manage the situation. These conditions indicate that the retention pond—as the end-of-system component serving as the outlet for the entire area's drainage flow—has not been able to optimally accommodate peak discharge. Provisions regarding the implementation of retention basins and detention basins in urban drainage systems are regulated in Ministry of Public Works and Public Housing Regulation No. 12/PRT/M/2014; retention basins and detention basins are forms of urban drainage infrastructure used to collect, control, and manage stormwater runoff to reduce flooding.

Retention basins are temporary water storage facilities that serve to mitigate peak runoff by holding excess rainwater and gradually releasing it into receiving water bodies [5]. Urban flood management is essentially hierarchical, encompassing drainage channel normalization as a short-term measure, retention pond redesign as a medium-term structural intervention, and land-use planning as a long-term policy [2]. This study focuses on the medium-term intervention stage by defining the existing conditions of drainage channels as a "fixed hydrological loading" scenario—an approach commonly applied in hydraulic engineering to test design resilience under suboptimal system conditions [6]. Retention ponds that were not designed based on current hydrological data tend to experience functional degradation as the proportion of impervious land within their catchment area increases [7]. Based on this background, this study aims to evaluate and redesign the existing retention pond in the Danita Irrigation Housing Complex, East Bekasi, to assess the redesigned system's ability to reduce flooding even though its supporting drainage system is not yet operating optimally.

2. Method

The research was conducted from February through April 2026 at the Danita Irrigation Housing Complex, RT.001/RW.014, Bekasi Jaya Village, East Bekasi Subdistrict, Bekasi City, West Java Province, located at coordinates 6°13′48.3″ S and 107°00′54.7″ E. A map of the research location is shown in **Figure** 1.



Figure 1. Map of the Study Location

2.1. Tools and Material

The study utilized primary data in the form of field measurements (channel dimensions, sediment thickness, and geodetic GPS elevations converted to orthometric height using INAGEOID2020), as well as secondary data in the form of daily rainfall records from CHIRPS and the BMKG Kemayoran (2015–2024), basemaps, DEMNAS contour lines, and RBI administrative maps. The analysis was conducted using Google Earth, ArcGIS, AutoCAD, EPA SWMM 5.2, Microsoft Excel, and Microsoft Word.

2.2. Procedure

2.2.1 Data Collection

The research data consists of primary and secondary data. Primary data was obtained through direct observation of the condition of retention ponds and drainage networks in the field, while secondary data includes rainfall data, basemaps, and contour maps sourced from the Bekasi City Public Works and Water Resources Agency, the BMKG, and the RBI.

2.2.2 Data Processing and Analysis

Data processing and analysis involved analyzing rainfall data, determining subcatchments, and modeling using EPA SWMM 5.2 to determine the maximum design discharge. The simulation results—including runoff data, discharge and flow depth at nodes and conduits, and outlet capacity—were then used to evaluate existing capacity and serve as the basis for the redesign of the retention basins.

3. Result and Discussion

3.1. Condition of Resesarch Locations

The study was conducted in the Danita Irrigation Housing Complex in East Bekasi, covering a watershed area of 24.1 ha. This area is located at an elevation of 11–18 meters above sea level and has a bowl-shaped topography, where surface runoff flows from the southern part (RW 11) toward the lowest point near the retention pond (RW 14). The channel bed elevation ranges from ±29.5–34 m (ellipsoidal height), with the dominant flow direction toward the main channel on the eastern side, which connects to the Bekasi Sub-Watershed. These topographic characteristics cause surface runoff to concentrate in the retention pond, thereby increasing the risk of flooding if the pond's storage capacity is insufficient. The DTA map, along with the ellipsoidal height contours of the channel bed derived from field measurements, is presented in **Figure 2**.

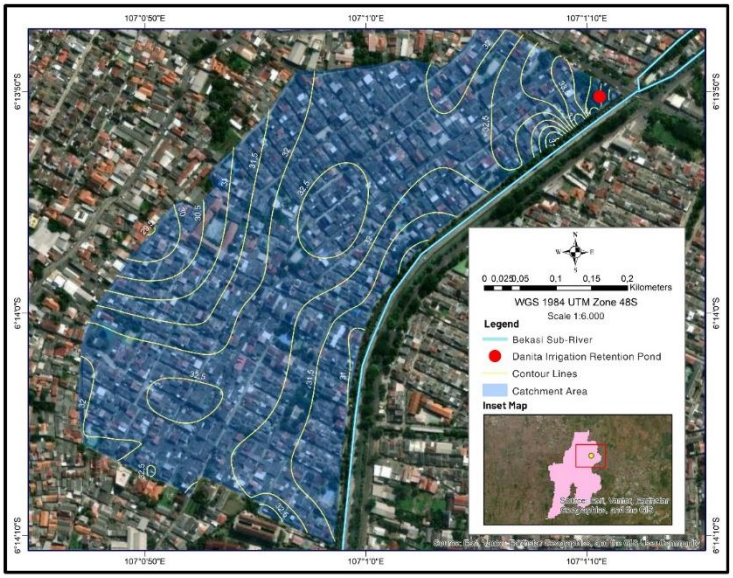


Figure 2. DTA and ellipsoidal height contour of the base of the Danita Irrigation Housing channel

The existing drainage system has experienced a decline in hydraulic capacity due to sedimentation at the bottom of the channels, with a thickness of 5–40 cm, exacerbated by the accumulation of trash and the growth of invasive vegetation along the channels. The existing retention pond, with an area of approximately 560 m², is also not operating optimally, as its storage capacity is not commensurate with the volume of runoff entering from the watershed. These conditions are consistent with Suripin's (2004) assertion that the effectiveness of a retention pond is highly dependent on the match between its storage capacity and the characteristics of the runoff from the watershed it serves [8]. Documentation of the existing conditions at the study site is presented in **Figure 3**.



Figure 3. Existing Conditions of Research Locations

3.2. Analysis of Maximum Daily Rainfall and Design Rainfall

The rainfall data used in this study were derived from a combination of CHIRPS satellite data and observational data from the BMKG Kemayoran Station (2015–2024), which have undergone a correction process. Data correction is necessary because remote sensing-based rainfall estimates may be biased relative to actual field conditions [9], so a bias correction process is required to improve the accuracy and reliability of the data used [10]. A comparison between the observation station data and the satellite data is presented in **Figure 4**, while the correction factor class intervals used as the basis for adjusting the rainfall data are shown in **Table 1**.

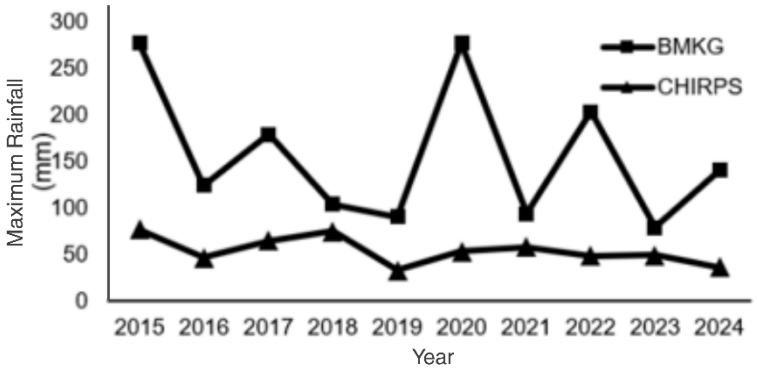


Figure 4. Comparison of BMKG Rainfall Data with CHIRPS Data

Table 1. Rainfall correction value class intervals

Interval (mm/day)	BMKG data (mm)	CHIRPS data	Correction factor
5-30	12,637.2	16,056.73	0.79
30-55	1,209.7	2,839.74	0.43
55 - 115	163.6	333.10	0.49

Table 2. Corrected maximum daily rainfall

Year	Max data (mm)	Year	Max data (mm)
2015	37.92	2020	22.98
2016	20.10	2021	28.81
2017	32.11	2022	20.94
2018	36.84	2023	21.12
2019	14.30	2024	15.75

The Rmax results in Table 2 were then analyzed statistically, yielding a standard deviation of 8.38, a Cv of 0.33, a Cs of 0.42, and a Ck of 2.86. Of the several distributions tested, only the Gumbel distribution met the statistical criteria and was deemed suitable based on the chi-square and Smirnov-Kolmogorov tests.

Table 3. Planned Rainfall Recurrence Interval [11]

City typology	Watershed area (Ha)			
	<10	10-100	101-500	>500
Metropolitan City	2 years	2-5 year	5-10 year	10-25 year
Big City	2 years	2-5 year	2-5 year	5-20 year
Middle City	2 years	2-5 year	2-5 year	5-10 year
Small City	2 years	2 years	2 years	2-5 year

Tabel 4. Planned Rainfall Recurrence Interval

Probability(year)	Rainfall design (mm/hour)
2	24.27
5	34.27
10	40.89
25	49.26
50	55.47

According to 2023 data from the Ministry of Home Affairs, the population of Bekasi City was recorded at 2,513,669, classifying the city as a metropolitan area [12]. Referring to Table 3, the 24.1 ha DTA located in the metropolitan area is required to use a 5-year design rainfall return period, and the calculation results yield a design rainfall of 34.27 mm, as presented in Table 4. Rainfall intensity was calculated using the Mononobe method as time-series input for EPA SWMM 5.2 and visualized as an Intensity-Duration-Frequency (IDF) curve in **Figure 5**.

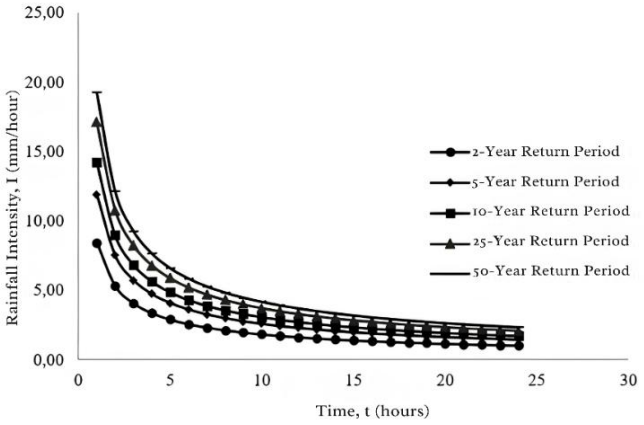
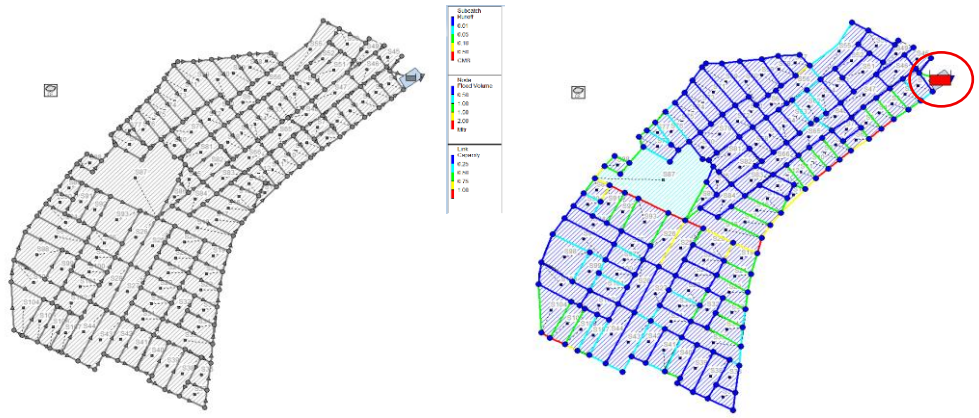


Figure 5. IDF Curve for the Planned Rainfall Recurrence Period

3.3. Hydraulic analysis

Hydraulic analysis was conducted using EPA SWMM 5.2 software to evaluate the performance of the existing drainage system and retention ponds through an integrated rainfall–runoff simulation [13]. The model was constructed with 107 subcatchments, 190 junctions, 307 conduits, 1 storage basin, and 2 outfalls, where subcatchment parameters were entered based on the physical characteristics of the land, including area, width, slope, N-imperv, N-perv, D-store imperv, and D-store perv, which directly influence the amount of surface runoff. Conduits were modeled as square channels with dimensions of 0.4 m × 0.4 m for secondary channels and 1 m × 1 m for main channels, while the retention pond was modeled with an area of 560 m² and an effective depth that decreased from 4 m to 2.71 m due to sediment deposition. The simulation was run using a 5-year return period design rainfall in the form of a 3-hour time series, based on Ginting's study of the Kali Bekasi watershed, which showed that the effective rainfall duration in that area ranges from 1 to 3 hours [14]. The modeling scheme and simulation results for the existing conditions are presented in **Figure 6a** and **Figure 6b**, respectively.



(a) **(b)**

Figure 6. Modelling on EPA SWMM 5.2 **(a)** scheme model, **(b)** result simulation

An evaluation of the existing conditions based on the results of the EPA SWMM 5.2 simulation was conducted using two scenarios: the retention pond conditions with sediment present (prior to normalization) and the conditions following sediment dredging (after normalization). In the pre-normalization scenario, sediment accumulation caused a reduction in the pond's storage capacity, resulting in a flood volume of 3.525 × 10^6 liters, indicating that the drainage system was not yet capable of optimally accommodating the runoff volume. Based on this, retention pond normalization was carried out as an effort to restore the pond's storage capacity to its original condition. A summary of the simulation results for both scenarios is presented in **Table 5**.

Table 5. Result Simulation on EPA SWMM 5.2 2nd Simulation

Parameter	Existing Condition
Existing retention pond area	560 m²
Existing retention pond depth	4.0 m
Existing retention pond volume	2,240 m³
Average simulated volume (EPA SWMM 5.2)	1,102 m³ (49.2% full)
Maximum simulated volume (EPA SWMM 5.2)	2,240 m³ (100% full)
Time of maximum simulated volume	Day 0, 02:35
Flooding volume at the retention pond (EPA SWMM 5.2)	0.623 × 10^6 Ltr = 623 m³
Other nodes experiencing flooding	J129 (0.005 × 10^6 Ltr), J188 (0.018 × 10^6 Ltr)
Maximum retention pond outflow	0.090 m³/s
Maximum retention pond inflow	0.712 m³/s
Duration of flooding at the retention pond	0.40 hours

Based on **Table 5**, the minimum storage capacity requirement for the retention pond was determined to be 2,863 m³. By applying a safety factor of 1.5 in accordance with SNI 8460:2017, the resulting design capacity of the retention pond is 4,294.5 m³, rounded to 4,300 m³, which will serve as the reference for the redesign of the retention pond to optimize flood control. Given the limited availability of green open space (RTH) in the Danita Irrigation Housing Complex, increasing the pond depth to 5.0 m was chosen as the solution, resulting in a required retention pond area of 860 m² and an additional land requirement of 300 m² beyond the existing area. The results of the post-redesign simulation are presented in **Figure 7**.

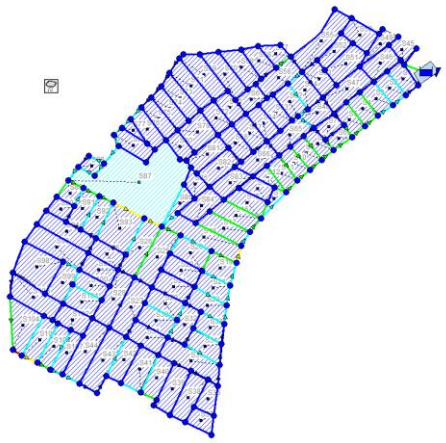


Figure 7. Simulation result after-*Redesign*

Tabel 6. Summary of Node Flooding After the Redesign in EPA SWMM 5.2

Node	Flooding Duration (h)	Maximum Flooding Rate (m³/s)	Flooded Volume (10^6 L)	Peak Flooding Time
J129	0.20	0.010	0.005	02:00
J188	1.36	0.009	0.018	02:00

The post-redesign simulation results in Figure 8 show that all subcatchments in the Danita Irrigation Housing Complex successfully channeled runoff into the retention pond without causing flooding in the drainage network, as indicated by the absence of red markers at junctions and conduits in the residential area. The redesigned retention pond, with an area of 860 m² and a depth of 5 m, is capable of reducing ponding by up to 100% within the pond area, making the design hydraulically feasible. However, based on the node summary in Table 6, ponding is still identified at nodes J129 and J188, with durations of 0.20 hours and 1.36 hours, respectively. These conditions indicate that the limited capacity of the supporting drainage channels due to sedimentation also contributes to the residual flooding occurring outside the basin area, meaning the overall system performance is not yet fully optimal. This is consistent with the statement by Birkinshaw and Krivtsov (2022) that retention basins are effective in reducing peak flow and improving the performance of urban drainage systems, even in areas with limited channel capacity [15]. Thus, the redesign of retention basins has proven to be a strategic structural solution for urban flood control, although comprehensive optimization still requires improvements to the supporting drainage system.

Nevertheless, the pump performance simulation showed that the peak inflow into the pond reached 0.712 m³/second, while the total pumping capacity was only 0.09 m³/second—comprising 0.03 m³/second from Pump P1 and 0.06 m³/second from Pump P2. This condition, where Qin > Qpump, caused the pond water level to continue rising to approximately 3.2 m during the simulation period, as

shown in **Figure 8**. This indicates that the capacity of the existing pump system is insufficient to optimally discharge runoff, thus requiring a capacity increase. The simulation results for the existing pumps are presented in **Figure 8**.

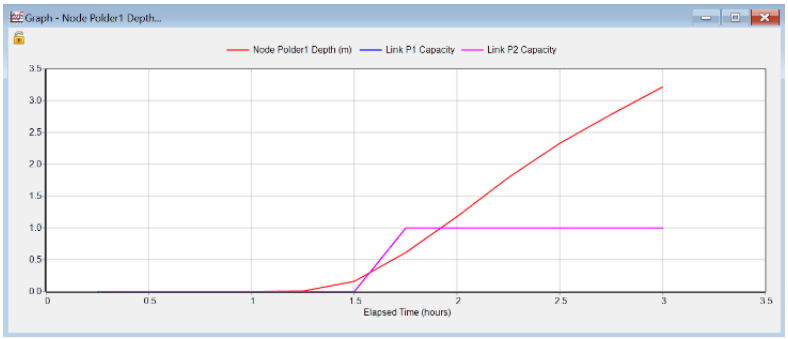


Figure 8. Simulation Results of Existing Pumps

3.3. Retention Pond Design Plan

Tabel 7. Specifications for the Redesign of the Retention Pond

Design Specification	Dimension	Unit
Retention pond area (A)	860	m²
Existing retention pond depth (Hr)	5	m
Retention pond depth (Hr)	6	m
Freeboard height [11] (W = Hp − Hr)	1	m
Retention pond volume capacity without freeboard (CPtj = A × Hr)	4,300	m³
Retention pond volume capacity with freeboard (CPdj = A × Hp)	5,160	m³
Design flood volume (Vb)	2,863	m³
Remaining retention pond capacity without freeboard (CPstj = CPtj − Vb)	1,437	m³
Remaining retention pond capacity with freeboard (CPsdj = CPdj − Vb)	2,297	m³

Based on Table 7, the redesigned retention pond has an area of 860 m², a total depth of 6 m—comprising a design water level of 3.00 m and a freeboard of 1.00 m—and a storage capacity of 4,300 m³ without freeboard and 5,160 m³ with freeboard. With a design flood volume of 2,863 m³, this design is capable of reducing flooding in the retention basin area by up to 100%, leaving approximately 50% of the storage capacity unused. Top views, cross-sections, and embankment details are presented in Figures 9 through Figure 12.

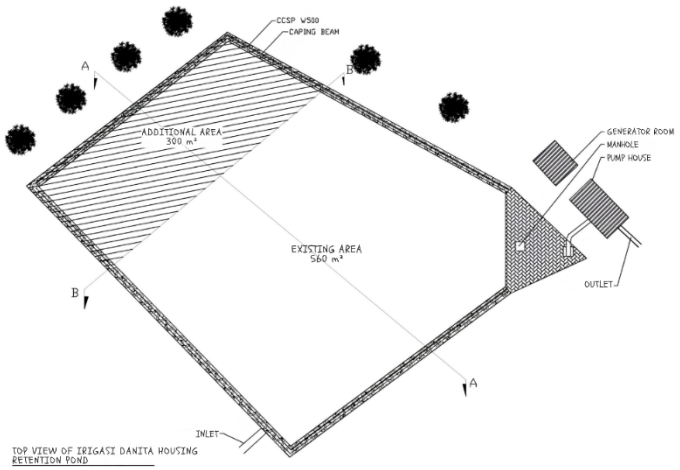


Figure 9. Top View of the Redesigned Retention Pond

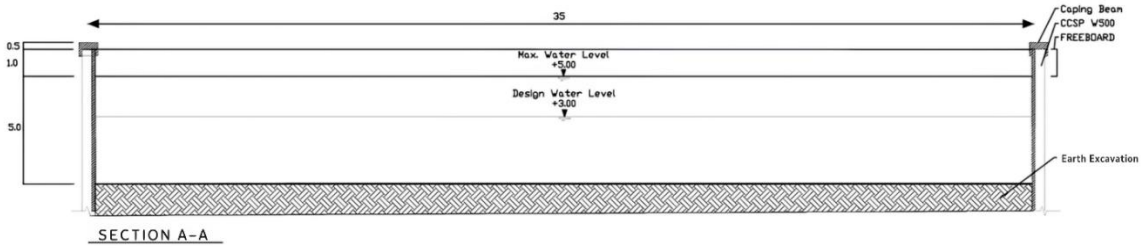


Figure 10. Cross-Section A-A of the Retention Pond

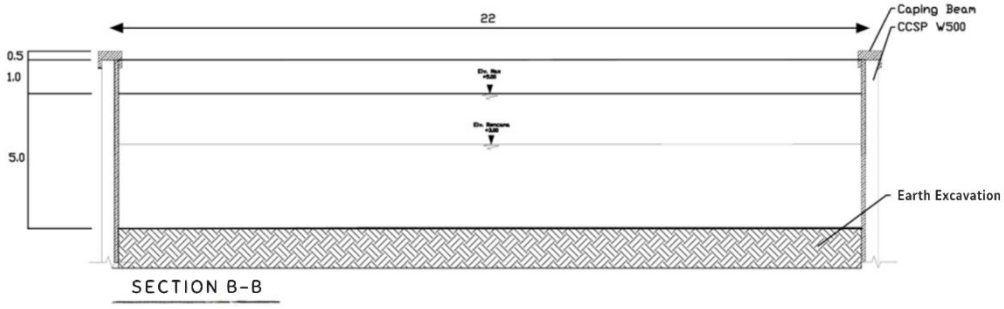
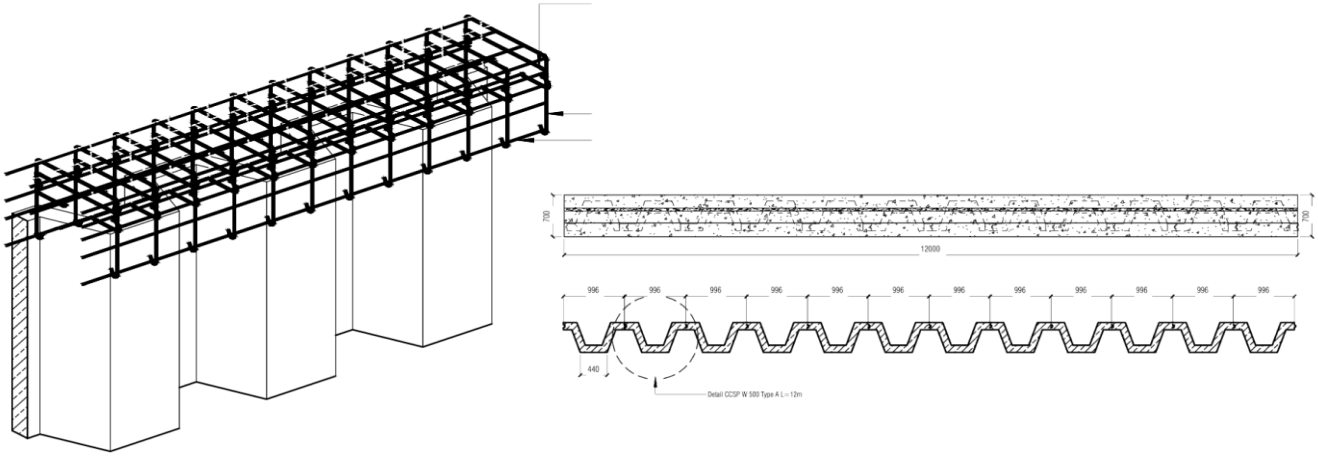


Figure 11. Cross-Section B-B of the Retention Pond



(a) **(b)**

Figure 12. Pond Embankment Details, **(a)** Details of the Embankment Reinforcement, **(b)** Detail CCSP W500

3.3.Bill of Quantity (BoQ)

The *Bill of Quantity (BoQ)* for the redesign of the retention pond at the Danita Irrigation Housing Complex in East Bekasi was prepared in accordance with Ministry of Public Works and Public Housing Regulation No. 68 of 2024, the Bekasi Mayor's Regulation on Base Prices for 2024/2025, and the 2024 LKPP e-Catalog. The scope of work includes earth excavation and sediment dredging, disposal of excavated soil, procurement and installation of 69 CCSP W500 retaining wall piles, CCSP pile head cutting, and capping beam work. A summary of the budget for the entire scope of work is presented in Table 8 below, with a total construction cost before VAT of Rp 1,008,391,500.00 and, after adding 11% VAT, amounting to Rp 1,119,314,565.00, or rounded to Rp 1,119,315,000.00.

Tabel 8. *Bill of Quantity (BoQ)* pond *Redesign*

No	Work Item	Amount (IDR)	
I	Earthwork and Sediment Excavation	Rp	132,432,000,00
II	Disposal of Excavated Soil to Disposal Area	Rp	308,089,500,00
III	Procurement and Installation of CCSP W500 L = 12 m	Rp	449,017,500,00
IV	CCSP Head Capping Work	Rp	1,897,500,00
V	Capping Beam Work	Rp	116,955,000,00
Total Construction Cost (before VAT)		Rp	1,008,391,500,00
VAT 11%		Rp	110,923,065,00
Total Construction Cost (including 11% VAT)		Rp	1,119,314,565,00

4. Conclusion

The existing drainage system and retention ponds in the Danita Irrigation Housing Complex, East Bekasi, have experienced a reduction in capacity due to channel sedimentation ranging from 5 to 40 cm in height and sediment deposits in the ponds up to 2.71 m thick, exacerbated by the basin's topography at elevations of 11–18 meters above sea level, which causes runoff to concentrate at a single point. Results from an EPA SWMM 5.2 simulation using a 5-year return period rainfall input of 34.27 mm with a duration of 3 hours show that the flood volume under existing conditions reaches 3.525×10^{6} liters, confirming that the existing drainage system's capacity is insufficient to optimally accommodate the runoff load. The retention pond was redesigned with a minimum capacity of 2,863 m^3 and a design capacity of ±4,300 m^3 using a safety factor of 1.5, achieved by increasing the depth to 5 m and the area to 860 m^2. This design was proven capable of reducing flooding by 100% within the pond area, with remaining storage capacity of approximately 50% of the design flood volume. However, the condition where Qin > Qpump—with an inflow rate of 0.712 m^3/s, which far exceeds the existing pump capacity of 0.09 m^3/s—caused the pond water level to continue rising to 3.2 m throughout the simulation period. In addition, flooding was still identified at two points along the drainage channels; therefore, comprehensive flood control still requires an increase in pump capacity and integrated normalization of the drainage channels. The estimated construction cost for the retention pond redesign is Rp1,119,315,000.00.

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