Socio-Economic Analysis of Creating Coastal Reservoir in Welang Coastal Area, Pasuruan: Comparison with on-land Reservoir

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Abstract. Welang river is located in a residential area and national road access as well as a productive agricultural area which must be maintained. Floods that often hit the location disrupt economic activity and regional economic growth. The estuary and the capacity of the river sections, especially around the estuary are not able to accommodate and drain the flood discharge. The flood overflows caused inundation in Pasuruan, especially on national roads, agricultural lands, and industrial areas. To control the destructive power of the Welang river, it is necessary to plan an appropriate infrastructure for flood control in the Welang River especially when the high water discharge meets the high tide. This paper discusses the comparison between coastal and on-land reservoirs. In addition, based on economic analysis, the Benefit-Cost Ratio for on-land reservoirs is 1 and for coastal reservoirs is 1.54. Therefore, the coastal reservoir project is more economically feasible to carry out than an on-land reservoir with less social impact. This study also shows that with the use of the coastal reservoirs, the river runoff, water supply, and the water quality in Welang river basins can be improved.

1. Introduction
Development and civilization started with the availability of water in abundance. Since water is a fundamental resource for socio-economic development, people seek the place where the water is available and in most cases, it is in the flood plain. On the other hand, living in the flood plain to utilize water resources means that people also should accept the risk of disasters. Too much water causes flood and debris flow that threatens the human’s life and property, while a shortage of water causes a draught, which affects human activities that depend on the anticipated water. Therefore, people try to work on rivers to reduce the risk caused by natural hazards and develop strategies to live with residual risk. Water is a necessity of life for creatures in this world. No water, no life. The existence of water, other than according to the hydrological cycle, at a particular place, at a particular time, and in particular quality as well as quantity is greatly influenced by a variety of natural phenomena and also by human behavior. Properly managed water and its resources will provide sustainable benefits for life. However, on the other hand, water can also lead to disasters, when it is not managed wisely.

Therefore, it is highly necessary to conduct comprehensive and integrated water resources management efforts, or widely known as Integrated Water Resources Management (IWRM). In the same way, river management efforts as part of the river basin integrated water resources management,
including efforts on river utilization, development, protection, conservation and control, in an integrated river basin with cross-jurisdiction, cross-regional and crosssectoral approach. Nowadays, IWRM must be comprehensively arranged in coordination and collaboration with Integrated Coastal Zone Management (ICZM) for water resilience as stated on the Sustainable Development Goals (SDGs) especially SDG 13 and SDG 6 which are linked between Climate change adaptation and resilience and water, sanitation and hygiene.

Pasuruan is blessed with some rivers which carry a great quantity of water during the monsoon. A seasonal prevailing wind in the region of South and Southeast Asia, blowing from the southwest between May and September and bringing rain (the wet monsoon), or from the northeast between October and April (the dry monsoon), and at last end up in the sea. However, the rivers full of blessings also sometimes cause problems because the extreme weather with high rainfall results in high river discharge. Therefore, the river storage capacity is unable to accommodate it so that the water overflows into a runoff and causing flooding.

Welang River is one of the rivers that cross the Pasuruan Regency with the upstream of the river located in Mount Welirang. The watershed of Welang River covers the administrative area of Pasuruan Regency, with an area of ± 518 km² and a length of 72.37 km (the main river length is 39.21 km). The Welang river end in the Madura Strait. Figure 1 shows the Welang River crossed the Pasuruan Regency.

![Figure 1. The Welang River in Pasuruan Regency.](image)

Coastal reservoir (CR) is a very innovative concept that has the potential to store the flood water of rivers joining the sea and meet the water requirement of water-starved cities. A freshwater reservoir near the coast would bring a positive transformation in the Welang estuary in terms of cleanliness, living standard of the people, human resource development, and livelihoods.

2. Study Area

Pasuruan Regency with 1,474,015 km² area is located between 112°33’55“- 113°05’37“ Longitude and 7°32’34“ -7°57’20“ Latitude. This area is economically very strategic because it is a crossroads from Surabaya - Malang, Surabaya - Probolinggo, and from the direction of Probolinggo to Malang, which goes through the Pasuruan regency route. According to the area in Pasuruan Regency, the areas that have the largest area are Lumbang District, Prigen District, and Purwodadi District, each of which has an area of 125.55 km² (8.51 percent); 121.90 km² (9.82 percent); and 102.46 km² (6.95 percent). Divided into three geological areas, namely hilly areas, lowland areas, and coastal areas. This regency is an area
that has both flat and mountainous areas with an altitude of 0 to more than 1,000 m above sea level. About 20.83 percent of the area is at an elevation between 0 - 60 cm (lowlands); around 42.83 percent of the area has an elevation of 61 - 90 cm; and about 36.34 percent of the area has an elevation more than 90 cm above sea level. In terms of the slope, 66.85 percent of the area has an area of 0-15 degrees; 15.07 percent of the area has a slope between 15-40 degrees; and 18.08 percent of the area has a slope of over 40 degrees.

Topographically, the condition of Pasuruan Regency can be described based on its slope and altitude. The slope level of Pasuruan Regency includes:

a. Slope 0-2%: all Districts of Bangil, Rembang, Kraton, Pohjentrek, Gondangwetan, Rejoso, and Lekok, parts of Pasrepan, Kejayan, Wonorejo, Winongan, Grati and Nguling Districts.

b. Clarity of 2-5%: part of the subdistricts of Purwodadi, Tosari, Lumbang, Pasrepan, Kejayan, Wonorejo, Porwosari, Prigen, Sukorejo, Pandan, Gempol, Beji, Winongan and Lekok.

c. Slope 5-8%: part of subdistricts Purwodadi, Tutur, Pasrepan, Kejayan, Wonorejo, Porwosari, Prigen, Sukorejo, Pandan, Gempol, Beji, Winongan and Lekok.

d. Slope 8-15%: some subdistricts Purwodadi, Tutur, Pasrepan, Kejayan, Wonorejo, Porwosari, Prigen, Sukorejo, Pandan, Gempol, Beji, Winongan and Lekok.

e. Slope 15-25%: parts of Purwodadi, Tutur, Pasrepan, Kejayan, Sukorejo, Pandan, Prigen, Gempol and Beji sub-districts.

f. Slope 25-45%: parts of Purwodadi, Tutur, Pasrepan, Kejayan, Sukorejo, Pandan, Prigen, Gempol and Beji Districts.

g. Slope> 45%: parts of Tutur, Pasrepan, Kejayan, Sukorejo, Pandan, Prigen and Gempol Districts.

Geologically, Pasuruan Regency is divided into 3 (three) parts. Both mountains and hilly areas extend to the south and west covering the Lumbang, Puspo, Tosari, Tutur, Purwodadi, Prigen, and Gempol district. Meanwhile, lowland area is in the middle of an area with high soil fertility. As a part of the lowland area, coastal area with a height between 2 m to 8 m asl which stretches to the north covering the district of Nguling, Rejoso, Kraton, and Bangil. Administratively, the Welang River area is included in the Pasuruan Regency where the watershed covers the area of 9 Districts (Kraton, Sukorejo, Wonorejo, Kejayan, Porwosari, Purwodadi, Tutur, Pasrepan, and Grati in Malang Regency). Welang River water comes from the surface and groundwater flows in the areas of Mount Arjuna (+3200 m) and Mount Bromo (+2400 m). The boundaries of the Welang River watershed are as follows:

- In the north: Pilang River, Madura Strait
- East side: Gembong River
- West side: Mount Arjuna
- South side: Mount Bromo

3. Potential and Existing Problems

3.1. Local Economic Growth in Welang Watershed

During the last five years, the economy of Pasuruan Regency has always shown a positive movement from year to year, as seen from Gross Regional Domestic Product (GRDP) at current prices and GRDP at constant prices. In 2014, economic activity based on current prices in Pasuruan Regency was able to generate an added value of Rp. 94.61 trillion, then in 2015 it became Rp. 103.60 trillion. Not different from GRDP on a valid basis, GRDP at constant prices has also increased every year. If the increase in GRDP at current prices is not only influenced by an increase in production but is also influenced by an increase in prices, then for GDP at constant prices the increase is only influenced by an increase in production, while the factor of price increase has been issued. In 2014, Pasuruan Regency generated GRDP at a constant price of Rp. 79.90 trillion then increased to Rp. 84.38 trillion in 2015.

GRDP based on the current price of Pasuruan Regency for the last two years has grown by Rp. 8.99 trillion, with the biggest development being in the processing industry sector which grew by 8.40. To
see the pattern of economic activity in Pasuruan Regency, it can be seen through the contribution of each sector to the formation of GRDP in Pasuruan Regency. Over time, there will be a shift in the contribution of each sector, there are sectors whose contribution is higher, and this will be accompanied by a decrease in the contribution of other sectors. At current prices, in the midst of uncertain economic conditions due to the global crisis, the manufacturing sector was able to contribute 55.92 percent to the total GRDP of Pasuruan Regency. The agricultural sector contributed 8.05 percent. During the last two years, Pasuruan district has experienced quite high economic growth, from 6.69 to 5.47.

Economic growth is calculated based on the increase in the volume of GRDP at constant prices between the year concerned and the previous year. The economy in Pasuruan Regency in 2019 grew by 5.47%. This condition shows a slowdown compared to 2018 which grew by 6.69%. Economic growth in 2019 was influenced by the three largest business fields, namely transportation and warehousing which grew by 8.40%, then the business field for providing accommodation, food, and beverages grew by 8.31%, and the processing industry grew by 6.72%. Meanwhile, 14 (fourteen) other business fields out of 17 (seventeen) business fields experienced an average growth of 4.15%.

### Table 1. The number of registered companies in the Welang watershed.

| Districts | Location | Total |
|-----------|----------|-------|
| Purwodadi | Upstream | 12    |
| Tutur     | Upstream | 15    |
| Tosari    | Upstream | 3     |
| Kejayan   | Upstream | 3     |
| Wonorejo  | Mid stream | 19 |
| Purwosari | Mid stream | 29 |
| Sukorejo  | Mid stream | 68 |
| Kraton    | Downstream | 16 |

Compared to 700 registered companies in Pasuruan regency, the number of companies in the Welang River Basin is more than 23% of the total companies in Pasuruan regency as shown in Table 1. Therefore the economic growth in the Welang watershed must be maintained in such a way so as not to be disturbed by disaster, especially the risk of flooding because more than 30% of companies are in the transportation sector.

3.2. Water Resources Potential

From the map of the watershed area (shown in Figure 2), the characteristic data, and main river discharge, it can be seen among the watersheds above the main river, that the Welang River flow rate is still lower than on the Rejoso River which has a smaller catchment area. This is due to the relatively short length of the Rejoso River so that the time of concentration is short and the discharge is large and flows fast downstream. This can be seen from the flood that occurred at the mouth of this river, which was bigger than the mouth of the Welang River. Both rivers are perennial which is rivers that have flow throughout the year, but the difference between the largest discharge in the rainy season and the smallest discharge in the dry season is very large. However, in the rainy season, the flow of these rivers is very large so that the water level is very high and some of them exceed the elevation of the dyke and overflow into the surrounding area, which causing flooding problems in the downstream area.
Figure 2. The Watershed of Welang River.

Figure 3. Sub-watershed in Welang with each catchment.

The Welang watershed has the potential for water resources with a volume of 612.17 million m³ per year. It is supplied by a relatively high annual rainfall of 1,554 mm. Theoretically, 66% of the untapped water resources of the Welang watershed are partially stored in the ground and the rest is wasted into the sea. Water consumption in the Welang watershed is 207.45 million m³ with a percentage of 34% compared to the total potential water resources. There needs to be an optimal use of water so that it is beneficial for life, sustainability, and human life balance. Figure 3 shows the sub-watershed in Welang with each catchment area so it can be seen which catchment gives a significant role in increasing water potential and can be compared with water consumption in that area.

The employee of Water Resource Management Technical Unit Welang Pekalen in Pasuruan said that if there is heavy rain in the upstream area, flooding will still occur in the Kraton District and other sub-districts downstream of the Welang River although there is no rain in the downstream area. Further study shows that this phenomenon occurred due to high discharge meets the sea tide. Not only that, the flat
topography of the downstream area causes the potential for sedimentation and there is a tidal influence in the estuary area worsen the flood problems.

3.3. Flood Problems
Welang watershed covers a residential area and national road access as well as a productive agricultural area which must be maintained to increase its production. Floods that often hit the location of the area disrupt economic activity so it can disrupt regional economic growth. The estuary and the capacity of the river sections, especially around the estuary (up to the 8 km long weir Licin), are not able to accommodate the flood discharge. The flood overflows caused inundation in Pasuruan City, especially on national roads, agricultural lands, and settlements as well as industrial areas. The duration of inundation is about 5-6 hours on average and occurs 1 to 2 times a year. In the last 2 years, there have even been massive floods every month during the rainy season. To control the destructive power of the Welang river, it is necessary to rehabilitate infrastructure for flood control in the Welang River and also to improve the operating system of the existing gates in order to get a good synergy in the water damage control system in the area. However, floods continue to occur, especially when the high water discharge from the upstream meets the high tide.

Flood-prone areas are defined by the criteria for areas that are identified as frequent and/or high-potential to experience floods. Most of the Pasuruan regency which is located in the coastal area is a flood-prone area. Areas that experience frequent flooding in Pasuruan Regency include Gempol, Beji, Rembang, Bangil, Kraton, Grati, Pohjentrek, Gondangwetan, Rejoso, Winongan and Lekok Districts. For more details, flood-prone areas can be seen in Figure 4.

The estuary area in the Welang watershed is a flood-prone area where its land is allocated in the form of fishponds. The size of the fishponds in the Welang River are 105.5 ha in Pulokerto Village and 268.6 ha in Semare Village, both are located in Kraton District. From the recorded data on floods that have occurred in Welang River for 10 years, the area of inundation was 1316.2 ha with the following distribution: Kraton District (1096.3 ha), Kejayan Subdistrict (172.7 ha), and Pohjentrek sub-district (47.2 ha).

![Figure 4. Flood Prone Area in Pasuruan Regency.](image_url)

Efforts to control floods and the destructive force of water so far has been carried out by rehabilitating flood control infrastructure. Floods that occur especially in the downstream part of the Welang river section have caused many regional economic losses. Floods in 2011, 2012, 2016, and 2018 were some of the events that were quite large and even crippled national road access for several hours. The Welang
river started to flood 8 years ago in 2008 which occurred along the Welang River and the Sumber Pinang tributary, even in 2010 the flood occurred during one rainy days in the dry season. As observed from the river capacity, especially at the estuary to the National Road Bridge with a length of +7 km, the river's capacity is no longer able to accommodate and drain the large flood discharge. The flood overflows caused inundation in Pasuruan and around its river basin. Especially on national roads during floods, the road cannot be crossed by vehicles due to a fairly high inundation, about 1 meter with an average duration of 5 hours to 12 hours which can occur 3 to 5 times a year. To control the problems above, efforts are needed not only to repair critical river embankments and river normalization, but also flood control systems in estuary areas that are worsened by high tides of seawater. A coastal reservoir as shown in Figure 5 is proposed.

![Figure 5. Concept of Coastal Reservoir in Welang River.](image)

4. Water Storage

4.1. Rainfall-Runoff Simulation
The simulation of Rainfall-Runoff will be performed using HEC RAS (Brunner, 2010) developed by the US Army Corps of Engineers. The rainfall calculation for the Welang River watershed plan will be divided into 3 sub-watersheds, namely the Domas sub-watershed, the Girang sub-watershed, and the Licin sub-watershed. Rainfall data for 10 years will be collected from three influential rain stations closest to the study location, namely the Wonorejo, Tutur, and Lawang rain stations as shown in Figure 6.

![Figure 6. Location of rain gauge and AWLR stations.](image)
The design flood is the flood scale used to determine the dimension of the flood control structure. The hydrology analysis result with HEC-HMS would generate maximum flood discharge, flood volume, and flood hydrograph. The design flood discharge with various return periods is shown in Table 2. Based on the hydrological analysis, the total runoff to be stored with Q25 is 1.8 million kilolitres.

Table 2. Return Periods of Welang River.

| Return Period (Years) | Peak Discharge (m³/s) |
|-----------------------|------------------------|
| 2                     | 206.58                 |
| 5                     | 240.13                 |
| 10                    | 237.58                 |
| 25                    | 277.89                 |
| 50                    | 324.37                 |
| 100                   | 388.27                 |

4.2. Creating Reservoir to Impound Runoff

A Coastal Reservoir is a freshwater reservoir located in the sea at the mouth of a river with a sustainable annual river flow. All coastal reservoir needs to be effective is an impermeable barrier between the fresh river water and the salty seawater. At first, the clean river needs to be separated from polluted water and saltwater. Second, protected the water, means the protection of collected freshwater against polluted river water and external pollution. The last is prevention, which means successfully prevent saltwater intrusion into the stored freshwater. Compared with water from seawater desalination processes, catchment runoff is a natural resource, which is cost-saving and water quality is more closed to drinking water.

Differ from the on-land catchment runoff, coastal reservoir harvests the catchment runoff in the sea, with water sources from a river and the reservoir has the potential to catch all runoff from a catchment. Existing freshwater lakes on the shore can be regarded as natural coastal reservoirs. The main differences between coastal reservoirs and on-land reservoirs are summarized in Table 3.

Table 3. The differences between On-land Reservoir and Coastal Reservoir.

| Item          | On-land Reservoir        | Coastal Reservoir |
|---------------|--------------------------|-------------------|
| Dam-site      | Valley (limited area)    | Coast             |
| Land acquisition | High                   | Low               |
| Water level   | Above sea level          | At sea level       |
| Pressure      | High pressure            | Low pressure      |
| Seepage       | By head difference       | By density        |
Table 3 shows when a coastal reservoir has been built, it shares many similarities to on-land reservoirs but due to the presence of water on either side which has almost the same density, the hard barrier does not need to be built as strong as on-land reservoirs. So the material and construction costs are lower. The coastal reservoir can be classified into various categories, in terms of location, barrage, and water quality, etc. According to the geographical location, it can be divided into estuary reservoir, intertidal reservoir, and gulf reservoir. According to the water quality, it can be divided into drinking water reservoir with good quality, the freshwater reservoir for agricultural or industrial purpose with moderate quality, sewage reservoir, ballast water reservoir, etc. According to the dam body, it can be divided into a concrete dam, earth dam, and soft dam reservoirs. It also can be divided into a natural and artificial reservoir.

4.3. Socio-Economic Advantages of Creating Coastal Reservoir in Welang

The main advantage of a coastal reservoir is the capability of storing excess fresh water in the rainy season, which can be transferred further to near watersheds through artificial channels or pipelines. The freshwater can be utilized by people for drinking water and meet the needs of agriculture. Based on the environmental aspect, as there are nearly no land requirements to build Welang coastal reservoirs and water quality can be guaranteed, the damage to the local ecosystems and marine wildlife in Madura Strait can be minimized greatly. The proposed method of impounding will avoid any severe environmental impacts.

Welang reservoirs has the ability to capture every single drop of runoff, it will always be functional as long as the rain continues to fall. Coastal reservoirs will not lead to flooding, as the water collected is in the ocean. When there is too much water which may occur during long rainy periods, the excess water will be drained into Madura Strait and prevent flooding.

Based on the location aspect, Welang coastal reservoirs can fit into any location at the mouth of a river (river estuary). This is very convenient for Pasuruan as a coastal city which has huge population and less space. Welang coastal reservoirs can be built near the estuary in the Madura Strait, there is almost no relocation cost for the Pasuruan residents. On-land reservoirs located upstream can affect large amounts of people, especially when damming major valleys. There is no need to relocate many people while some other infrastructure may still require property acquisition.

The potential use of Coastal reservoirs is high as the storage volume can be expanded at most sites, while on-land reservoirs can’t be changed as the initial design is usually for maximum possible yield. It is also not difficult for desalination to enlarge or to reduce water yield, which only needs more desalination plants that can be built at the coast if the energy needed is available. Wastewater recycling is similar to desalination, which needs more wastewater treatment systems. Table 4 shows a typical comparison of construction cost and cost per kilolitre of water between coastal reservoirs and other water solutions in Australia.

*Table 4. Relative Comparison of Coastal Reservoir to on-land reservoir.*

|                         | Coastal Reservoir per kilolitre of water (US$) | On-land Reservoir per kilolitre of water (US$) |
|-------------------------|----------------------------------------------|-----------------------------------------------|
| Construction cost       | 2.67 - 6.01                                  | 5.83 - 7.5                                    |

The data of the table is based on the conditions in Australia. The construction cost per kilolitre of water and cost per kilolitre of water of coastal reservoirs are calculated based on the existing coastal reservoirs in the world. For inland reservoirs, the data is based on statistical data of the United Nations. When compared with the proposal of on-land reservoirs, the method of coastal reservoirs has no cost to cover the inundation of land and people’s relocation, normally this is very expensive and could be more than half of the dam’s construction cost. The coastal reservoir can be located close to the high demand area. Water demand is related to population growth, in theory, population increases in coastal areas are
much higher relative to the on-land regions, and hence the water demand in coastal regions is likely to continue to be higher than on-land regions. The future water demand in coastal regions is difficult to meet by developing more on-land reservoirs as it needs an ideal combination of suitable hydrological, geological, and topographic conditions. Although there are rare cases of water scarcity in Pasuruan regency, in surrounding areas such as Probolinggo Regency and Madura Island, there are still difficulties in getting water in the dry season. The Welang Coastal Reservoir is able to store water reserves that run over during the rainy season for use during dry season. Therefore, the coastal reservoir will play a more and more important role in the development of freshwater resources in the near future.

5. Economic Analysis

5.1. Calculation of Loss due to Flooding
The total losses incurred due to flooding in the Welang River Basin are calculated. Based on flood data during 2014-2019, data was obtained that several main sectors suffered financial losses, namely housing, roads, agriculture, industry, and public facilities such as schools, bus stations, and traditional markets. Of these five sectors which are assumed to be calculated as losses in this research are housing, roads, agricultural land, and industry. Public facilities are not calculated financially. The total loss was 3.61 million US $ or the equivalent of 53.39 billion rupiah.

| Table 5. Calculation of Loss. |
|--------------------------------|
| No  | Affected by Flood | Loss (USD/ ha) | Sum       |
|-----|-------------------|----------------|-----------|
| 1   | Housing           | Rp 27,969,952.012 | $1,893,572.00 |
| 2   | Transportation / National Road | Rp 3,501,280.912.50 | $237,037.50 |
| 3   | Residential Road  | Rp 2,134,114.080 | $144,480.00 |
| 4   | Farming Sector    | Rp 17,491,818.200 | $1,184,200.00 |
| 5   | Industrial Sector | Rp 2,294,970.270 | $155,370.00 |
|     | Public Facilities | Rp 53,39,135,474.50 | $3,614,659.50 |

5.2. EIRR for On-land Reservoir
In calculating the construction needs for the construction of an on-land reservoir using the cost ratio according to Australia Water Resources publishing journal. For on-land reservoir and coastal reservoir, the construction cost per kilolitre in US $ has a ratio of 7.5: 6.01 assumed from the upper limit ratio.

To validate the calculations based on this ratio, it involves two reservoirs located in East Java Province, namely the Wrati River in Sidoarjo- Pasuruan, and the Bajulmati River in Banyuwangi-Situbondo Regency. For Wrati River, the on-land reservoir involved in this research still in the form of a proposal planning, while the on-land reservoir at Bajulmati River has been built since 2016 with the assumption that there has been no significant inflation for the last 4 years and the dollar exchange rate used in this research is 1 US $ = IDR 14,771.00. Table 6 to 10 show the economic analysis of on land reservoir.

| Table 6. Comparison of the construction cost for on-land reservoirs. |
|--------------------------------|
| On-land Reservoir | Area (Ha) | Ratio | Volume runoff Q25 | Construction |
|-------------------|-----------|-------|------------------|-------------|
|                   |           |       | 10^9 m^3  | m^3       | kilolitre | US$     | Rp      |
| Welang            | 518       | 7.5   | 1,836         | 1,836,149  | 1,836,149.09 | 13,771,118.14 | 203,413,186,026.66 |
| Wrati             | 76.302    | 7.5   | 3,201         | 3,201,000  | 3,201,000.00 | 24,007,500.00 | 354,614,782,500.00 |
| Bajulmati         | 768.68    | 7.5   | 10,000        | 10,010,000 | 10,010,000.00 | 75,075,000.00 | 422,000,000,000.00 |
Table 7. Comparison of land acquisition and total cost for on-land reservoirs.

| On-land Reservoir | area (Ha) | Land Acquisition per Ha (Ha) | Estimation | Rp | Total US$ million |
|-------------------|-----------|-------------------------------|------------|----|------------------|
| Welang            | 518       | 62.0                          | 747,234,662 | 46,291,200,935.37 | 249,704,386,962.02 | 16,905,042.78 | 16.91 |
| Wrati             | 76.302    | 65.7                          | 747,234,662 | 49,061,186,218.89 | 403,675,968,718.89 | 27,328,953.27 | 27.33 |
| Bajulmati         | 768.68    | 91.9                          | 747,234,662 | 68,693,282,500.00 | 490,693,282,500.00 | 33,220,044.85 | 33.22 |

Table 8. The calculation for 10 years cost.

| No | Item | Cost | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|----|------|------|---|---|---|---|---|---|---|---|---|---|----|
| 1  | investment | 249,704,386,962.02 | | | | | | | | | | |
|    | 1 construction | 1,929,000,000.00 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 |
|    | 2 OM Total benefit | 251,633,386,962.02 | 249,704 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 | 1,929 |
|    | 3 loss total benefit | 53,392,135,474.50 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 |
|    | 4 depreciation 10% total | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 | 53,392 |
|    | 5 required interest rate then the project is feasible to be implemented | 24,970 | 24,970 | 24,970 | 24,970 | 24,970 | 24,970 | 24,970 | 24,970 | 24,970 | 24,970 |

Table 9. Calculation BCR for the on-land reservoir in Welang.

| Year | Const Cost | OM Cost | Total Cost | Benefit | Cash flow | B-C | P v | B-C/Pv | BPv | CPv | NPv |
|------|------------|---------|------------|----------|-----------|-----|-----|--------|-----|-----|-----|
| 1    | 249,704    | 1,929   | 251,633    | 53,392   | (198,241) | 1.20 | (165,201) | 44,493 | 299,694 | (487,594) |
| 2    | 1,929      | 1,929   | 53,392     | 51,463   | 51,463    | 1.44 | 35,738 | 37,078 | 1,340 | 74,106.92 |
| 3    | 1,929      | 1,929   | 53,392     | 51,463   | 51,463    | 1.73 | 29,782 | 30,898 | 1,116 | 88,928 |
| 4    | 1,929      | 1,929   | 53,392     | 51,463   | 51,463    | 2.07 | 24,818 | 25,749 | 930 | 106,714 |
| 5    | 1,929      | 1,929   | 53,392     | 51,463   | 51,463    | 2.49 | 20,682 | 21,457 | 775 | 128,057 |
| 6    | 1,929      | 1,929   | 53,392     | 51,463   | 51,463    | 2.99 | 17,235 | 17,881 | 646 | 153,668 |
| 7    | 1,929      | 1,929   | 53,392     | 51,463   | 51,463    | 3.58 | 14,362 | 14,901 | 538 | 184,402 |
| 8    | 1,929      | 1,929   | 53,392     | 51,463   | 51,463    | 4.30 | 11,969 | 12,417 | 449 | 221,282 |
| 9    | 1,929      | 1,929   | 53,392     | 51,463   | 51,463    | 5.16 | 9,974 | 10,348 | 374 | 265,538 |
| 10   | 1,929      | 1,929   | 53,392     | 51,463   | 51,463    | 6.19 | 8,312 | 8,828 | 312 | 318,646 |
| Total | 215,520   | 216,174 | 105,375    | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Table 10. Calculation EIRR for the on-land reservoir in Welang.

| Rate | Diff Pv | Diff Pv to Investment |
|------|---------|-----------------------|
| 20% | 487,593.89 | 739,227.28 |
| 44% | 74,106.92 | (72,177.92) |

IRR 22%
Required Rate of Return (RRR) 20%
Economic Internal Rate of Return (EIRR) 22.34%

EIRR > required interest rate (then the project is feasible to be implemented).

5.3. **EIRR for Coastal Reservoir**

Similar to the calculation for the on-land reservoir in Welang, the construction cost of the Welang coastal reservoir was estimated based on the cost ratio according to the Australia Water Resources publishing journal.
Table 11. Comparison of the construction cost for coastal reservoirs.

| On-land Reservoir | Area (Ha) | Ratio 10^3 m³ | Volume runoff Q25 (m³) | Construction Rp |
|-------------------|-----------|---------------|------------------------|-----------------|
| Bajulmati         | 76.302    | 6.01          | 1,836,149              | 203,413,186,026.66 |
| Wrati             | 76.302    | 6.01          | 3,201,000              | 354,614,782,500.00 |
| Welang            | 518       | 6.01          | 1,836,149              | 13,771,118.14    |

Table 12. Comparison of land acquisition and total cost for coastal reservoirs.

| On-land Reservoir | Area (Ha) | Land Acquisition per Ha | Estimation | Total Rp | Total US$ million |
|-------------------|-----------|-------------------------|------------|----------|------------------|
| Bajulmati         | 76.302    | -                       | -          | 338,162,666.666.67 | 22,893,688.08 |
| Wrati             | 76.302    | -                       | -          | 284,164,645,710.00 | 19,238,010.00 |
| Welang            | 518       | -                       | -          | 163,001,766,402.69 | 11,035,256.00 |

Table 13. The calculation for 10 years cost.

| No | Item | Cost | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|----|------|------|---|---|---|---|---|---|---|---|---|---|----|
| 1  | investment | | | | | | | | | | | | |
| 1  | construction | 163,001,766,403 | 849,000,000 | 163,002 | 849 | 849 | 849 | 849 | 849 | 849 | 849 | 849 |
| 2  | OM | | | | | | | | | | | | |
| 1 | benefit | 163,850,766,403 | 849,000,000 | 163,002 | 849 | 849 | 849 | 849 | 849 | 849 | 849 | 849 |
| 2  | total | 53,392,135,475 | 163,002 | 849 | 849 | 849 | 849 | 849 | 849 | 849 | 849 | 849 |
| 3  | depreciation | 163,002 | 163,002 | 163,002 | 163,002 | 163,002 | 163,002 | 163,002 | 163,002 | 163,002 | 163,002 | 163,002 |

Table 14. Calculation BCR for the on-land reservoir in Welang.

| Year | Total Cost | OM Cost | Benefit Cost | Cash flow | B-C | P v | B-C/Pv | BPv | CPv | NPv |
|------|------------|---------|--------------|-----------|-----|-----|--------|-----|-----|-----|
| 1    | 163,001.77 | 849.00  | 53,392.14    | (110,458.63) | 1.2 | (92,048.86) | 44,493.45 | 136,542.31 | (295,552.12) |
| 2    | 849.00     | 849.00  | 53,392.14    | 52,543.14  | 1.4 | 36,488.29 | 37,077.87 | 589.58 | 75,662.12 |
| 3    | 849.00     | 849.00  | 53,392.14    | 52,543.14  | 1.7 | 30,406.91 | 30,898.23 | 491.32 | 90,794.54 |
| 4    | 849.00     | 849.00  | 53,392.14    | 52,543.14  | 2.1 | 25,339.09 | 25,748.52 | 409.43 | 108,953.45 |
| 5    | 849.00     | 849.00  | 53,392.14    | 52,543.14  | 2.5 | 21,155.91 | 21,457.10 | 341.19 | 130,744.13 |
| 6    | 849.00     | 849.00  | 53,392.14    | 52,543.14  | 3.0 | 17,966.59 | 18,800.92 | 284.33 | 158,992.96 |
| 7    | 849.00     | 849.00  | 53,392.14    | 52,543.14  | 3.6 | 14,663.82 | 14,906.77 | 236.94 | 188,271.55 |
| 8    | 849.00     | 849.00  | 53,392.14    | 52,543.14  | 4.3 | 12,219.85 | 12,417.30 | 197.45 | 225,925.87 |
| 9    | 849.00     | 849.00  | 53,392.14    | 52,543.14  | 5.0 | 10,183.21 | 10,347.75 | 164.54 | 271,111.04 |
| 10   | 849.00     | 849.00  | 53,392.14    | 52,543.14  | 6.2 | 8,486.01  | 8,692.89  | 137.12 | 325,333.25 |

Total: 215,284.80 / 139,394.21 / 127,813.68

Benefit Cost Ratio (BCR) 1.54

Table 15. Calculation EIRR for the on-land reservoir in Welang.

| Rate | Diff Pv | Diff Pv to Investment |
|------|---------|-----------------------|
| 20%  | (295,552.12) | 459,402.89 |
| 44%  | 75,662.12   | (74,813.12) |

IRR 24%
Required Rate of Return (RRR) 20%
Economic Internal Rate of Return (EIRR) 23.91%
6. Conclusions

1. Hydrological analysis shows that total runoff at Welang watershed to be storage with return period of Q25 is 1.8 million kilolitres. Hence it is imperative that a small percentage of runoff of Welang is more than sufficient to cater to the water requirements of Pasuruan. From the data for a decade, a case of scarcity of water availability in the Welang watershed is quite rare. On one side, the surrounding area of Pasuruan Regency having a shortage of water, whereas a large quantity of water in Welang River is just flowing into the sea. This phenomenon brings out the current water storage strategies and explores new ways to tap the amount of runoff water to meet the water demands for East Java people which otherwise just flow into the sea. The concept of coastal reservoir emerges as the best solution to meet the future water demands of East Java.

2. Coastal reservoir shares many similarities to on-land reservoirs but due to the presence of water on either side which have almost the same density, the hard barrier does not need to be built as strong as on-land reservoirs. So the material costs are lower. Another main advantage of a coastal reservoir is storing excess fresh water in the rainy season, and then the freshwater can be transferred to the near area through artificial channels or pipelines. Last, the freshwater can be supplied to people to drink and meet the needs of agriculture. Not required mountainous areas, Welang coastal reservoir is better for existing infrastructure, environment and the people who need to relocate from the construction area like an on-land reservoir. Only high-quality water (free of contaminants) will be allowed to enter the reservoir, which will help to minimize the impact of the coastal reservoir on the local ecosystem and marine wildlife.

3. For economic analysis, the BCR value for on-land reservoirs is 1 and for coastal reservoirs is 1.54. Thus the coastal reservoir project is more feasible to carry out than an on-land reservoir.

4. This study shows that with the use of the coastal reservoirs, the river runoff, water supply, and the water quality in Welang river basins can be improved.

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