Alternatives for Beach Stormwater Outfalls: Preliminary Assessment for City of Naples

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There is an ongoing regulatory concern that runoff discharged to beaches via stormwater outfalls likely affects beach erosion, impacts turtle nesting habitat, and degrades water quality. Also, beach stormwater outfalls interfere with lateral beach access and degrade the aesthetics of the beach environment. The beaches in the City of Naples consist of long expanses of fine white sand, offering fantastic sunsets and spectacular views of the Gulf of Mexico, and are a worldwide attraction for seasonal residents and tourists. Preservation and protection of this precious natural resource is critically important to the City, which wants to mitigate impacts of stormwater outfalls on beaches through technically sound and economically feasible methods that also achieve its public safety and flood protection goals.

The City's stormwater drainage system consists of a series of 12 drainage basins that collect and convey stormwater to the Gulf of Mexico and other tidal water bodies within the City. The current study area is located in the City's Stormwater Drainage Basin II, which is one of the main basins serving the City, with a contributing area of approximately 920 acres. There are 10 stormwater outfalls (numbered 1 through 10) within Basin II discharging to the Gulf along Naples Beach. The outfalls are located between the Naples Pier to the south and approximately one-half mile north of the Naples Beach Hotel. Outfall #1 only serves private property and is privately owned and operated; therefore, it is not included in this study. All of the outfall pipes are buried beneath the upland beach profile and become exposed near the water line. Figure 1 shows the location of the City's existing beach outfalls.

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The following are the five beach stormwater outfall alternatives that are proposed to reduce the impacts of the outfalls on the beach, while

maintaining the same or slightly greater level of service as compared to the existing conditions:

1. Alternative 1: Integration of beach outfalls with planned beach renourishment project
2. Alternative 2: Integration of beach outfalls with aquifer storage recovery (ASR) system
3. Alternative 3: Consolidation of beach outfall pipes
4. Alternative 4: Redirection of beach outfall flows via pump station to alternate locations
5. Alternative 5: Extension of beach outfalls deeper and further into the ocean (subaqueous outfalls)

The proposed beach outfall alternatives were analyzed and evaluated using the City's existing stormwater system hydraulic model in XP–Stormwater Management Model. The objective of this evaluation was to define conceptual-level improvements needed for each alternative under the premise of maintaining or slightly improving the existing level of service in the existing system. The proposed beach outfall alternatives were incorporated into the hydraulic model and several simulations were performed using the five-year, 24-hour storm event for each alternative. The elements of each alternative were sized in an iterative process; the stormwater model was used for each iteration to evaluate the effects of the alternative on the peak stages for the selected storm event. A "pass or fail" criterion was used in this process; the stages under the proposed alternatives could be within 2 in. of the stages in the existing conditions model in order to be deemed acceptable.

Alternative 1: Integration of Beach Outfalls With Planned Beach Renourishment Project

The City's beach outfall Alternative 1 involves integration with the Collier County's planned beach renourishment project that includes modifying the existing coastal structures in the County to determine if the project's beach performance could be improved. The City's beach is constructed with a 1:10 slope that quickly (in a few months to a year) equilibrates to a natural slope. The recommended improvements for the City's outfall pipelines were estimated using the equilibrated templates and future shoreline locations. The baseline for these profiles was estimated using data from LiDAR (light detection and ranging), which is a remote sensing method to examine the surface of the earth and measure seafloor elevations.

Analysis of the City's outfall pipeline profiles indicated that Outfalls #2 and #3 be extended about 25 ft from the construction template shoreline in order to accommodate the County's planned beach renourishment con-

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Figure 1. Existing Beach Outfall Locations

Table 1. Proposed Infrastructure Requirements: Alternative 1

No.	Infrastructure Improvements	Quantity	Comments
1	Piping infrastructure	50 ft	30-in. diameter PVC pipe
		25 ft	18-in. diameter PVC pipe
2	Reinforcement of outfalls	NA	Reinforcement of existing outfalls to improve durability

Notes:

- Reference: Collier County beach renourishment project plans and drawings
- Proposed piping includes required joints, fittings, and supports as needed

Table 2. Proposed Infrastructure Requirements: Alternative 2

No.	Infrastructure Improvements	Quantity	Comments
1	Pump station with four pumps at design capacity of 50 cfs	1	Proposed pump station
2	Piping infrastructure	1,410 ft	60-in. diameter RCP pipe
		820 ft	54-in. diameter RCP pipe
		390 ft	48-in. diameter RCP pipe
		1,880 ft	42-in. diameter RCP pipe
		2,850 ft	36-in. diameter RCP pipe
		5,400 ft	8-in. diameter PVC pipe
3	Demolition of outfalls	NA	Outfalls to be sent to ASR and the rest of the flow to be discharged to the ocean via consolidated outfall at Outfall #6 location
4	New ASR wells and required appurtenances	2	Additional ASR wells at City's WWTP

Notes:

- Proposed piping includes required joints, fittings, and supports as needed

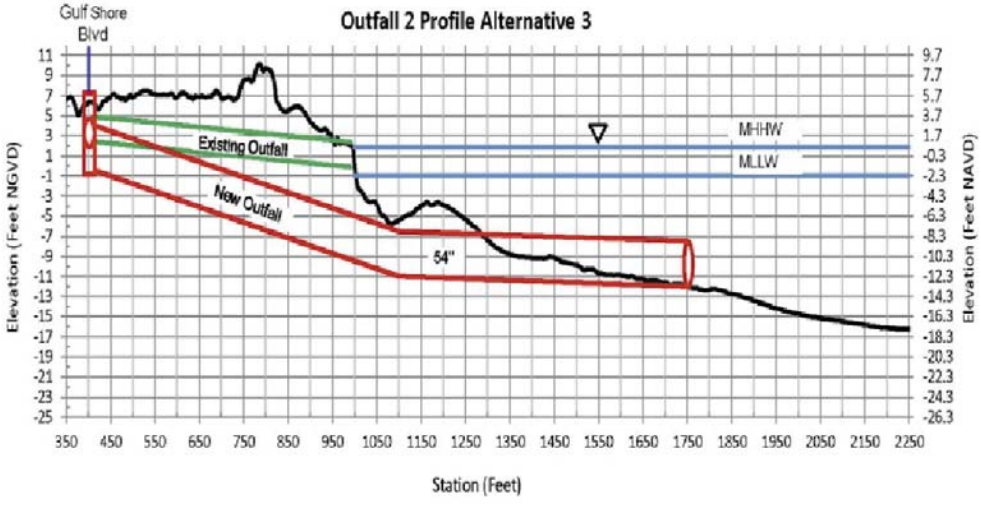

Figure 2. Outfall #2 Profile (Alternative 3)

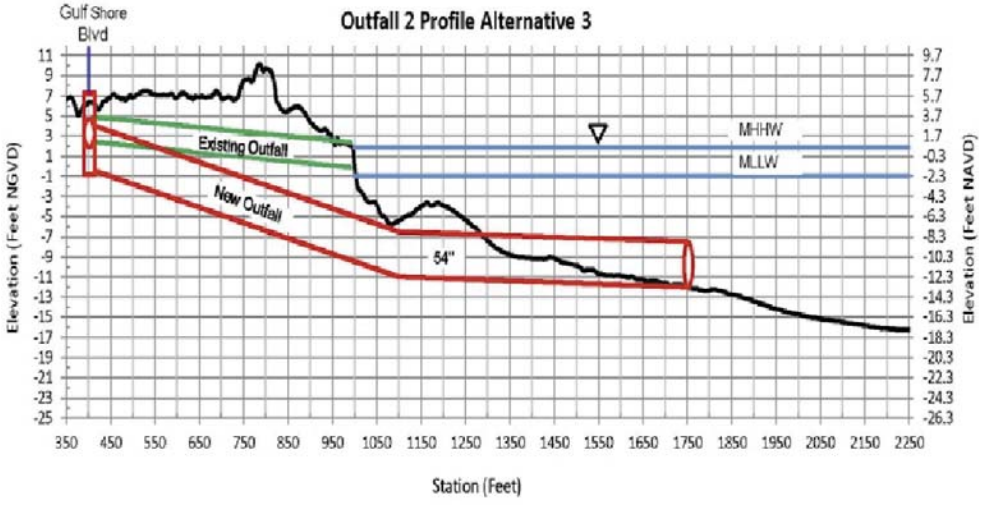

Figure 3. Outfall #6 Profile (Alternative 3)

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struction. Outfalls #4, #9, and #10 are taper-sectioned with small fill densities, and have sufficient length. Outfalls #5 through #8 are in gaps where no nourishment is needed, and the existing outfall length is sufficient. The durability of the existing outfalls has been fair to poor as reported by the City; therefore, reinforcement of all the existing outfalls was recommended to improve durability. Table 1 presents the proposed infrastructure improvements required for implementation of Alternative 1.

Alternative 2: Integration of Beach Outfalls With Aquifer Storage and Recovery System

The City's beach outfall Alternative 2 involves integration with the City's existing reclaimed water ASR system as an alternative to divert stormwater discharges that are currently going to the beach outfalls; however, since the redirection system (in this case, a pump station) will be limited by its capacity and by the available capacity of the ASR system, it will not be possible to redirect large portions of significant rainfall events. It might also not be feasible to redirect runoff produced by small rainfall events, since they will not produce the volume required to reduce salinity concentrations in the receiving water bodies. Additionally, the feasibility of this alternative is subject to the water quality of the stormwater discharges. The stormwater diverted may require pretreatment, including filtration and disinfection, prior to introduction to the ASR system.

For the current alternative, a base flow of about 2 mil gal per day (mgd), which is the available permitted capacity at the City's reclaimed water ASR system from Basin II outfalls, would be captured prior to discharge to the lake system and pumped to the City's ASR system, while the rest of the flow would be pumped to a consolidated outfall. The potential location for the consolidated pumped ocean outfall was identified based on findings from LiDAR data related to this project and is recommended to be at Outfall #6. This outfall is recommended to be upgraded to a larger-size pipe and the discharge location to be extended further into the Gulf from the current location. The evaluation of this alternative using the City's hydraulic model recommended a 60-in. force main extending about 1,210 ft from Gulf Shore Boulevard for the consolidated outfall at the Outfall #6 location. The recommended invert elevation for the consolidated outfall discharge location is approximately -12.5 ft with respect to National Geodetic Vertical Datum (NGVD) 1929.

A pump station will be required to pump flows from the outfalls to the proposed consolidated outfall and to the ASR system. The system required to pump stormwater to the ASR system

should keep the stormwater separated from the water in the lake to avoid its high salinity concentrations. In order to maintain the existing level of service, three pumps, with a design capacity of 50 cu ft per second (cfs) are required at the proposed pump station. A fourth pump with the same design capacity is recommended to serve as a standby pump. The proposed pump station would receive stormwater from the outfalls via gravity flow and then pump water at the required head for the proposed consolidated beach outfall at Outfall #6. A designated set of pumps at the proposed pump station would pump flow through a new force main that would carry flow to an existing gravity pipe, which conveys flow to the City's ASR. Table 2 presents the proposed infrastructure improvements required for implementation of Alternative 2.

Alternative 3: Consolidation of Beach Outfall Pipes

The City's beach outfall Alternative 3 involves consolidation of existing beach outfalls; the consolidated outfalls will be buried deeper and extend further into the Gulf. The following items need to be considered in the design of such submerged consolidated outfalls:

- Outfall diameter
- Outfall depth
- Outfall length
- Navigation markers
- Hydrostatic head
- Structural stability
- Outfall buoyancy
- Sea floor movement
- Stormwater dilution
- Biofouling

Flow from the outfalls is recommended to be consolidated into two beach outfalls and different locations could be selected for the consolidated beach outfalls; however, this alternative was based on the assumption that flows are conveyed to the largest outfalls. The LiDAR data related to this project was also considered in the selection of location for consolidated outfalls; Outfall #2 and #6 locations are recommended for consolidated outfalls under this alternative. Outfalls #2 and #6 have twin pipes, while the rest of the outfalls have a single pipe. Concept profiles that were developed using the cross sections from LiDAR data related to this project for Outfalls #2 and #6 are shown in Figures 2 and 3. All gravity flow with a single outfall could also be considered as another option for this alternative; however, a single gravity outfall will not maintain the same level of service as the existing condition, and therefore, a single gravity outfall is not considered a viable option.

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For Outfall #2, a 54-in. diameter conduit is recommended or, alternatively, two 42-in. conduits could be used. With the single 54-in. conduit, the concept design has the outfall extending approximately 750 ft offshore, with the last 450 ft only partially buried. The outfall invert at its terminus is at an elevation of -12 ft NGVD, which leaves a minimum clearance of 6.49 ft at mean lower low water (MLLW), not accounting for any rip-rap, support, or collar that would extend above the conduit. If this elevation can be raised 1 ft by using two 42-in. conduits, the outfall length could be reduced by about 120 ft.

Similarly, for Outfall #6, a 54-in. diameter conduit is recommended or, alternatively, two 42-in. conduits could be used. With the single 54-in. conduit, the concept design has the outfall extending approximately 570 ft offshore, with the last 250 ft only partially buried. The outfall invert at its terminus is at an elevation of -12 ft NGVD, which leaves a minimum clearance of 6.49 ft at MLLW, not accounting for any rip-rap, support, or collar that would extend above the conduit. If this elevation can be raised 1 ft by using two 42-in. conduits, the outfall length could be reduced by about 50 ft. Table 3 presents the proposed infrastructure improvements required for implementation of Alternative 3.

Table 3. Proposed Infrastructure Requirements: Alternative 3

No.	Infrastructure Improvements	Quantity	Comments
1	Piping infrastructure	2,490 ft	54-in. diameter RCP pipe
		820 ft	42-in. diameter RCP pipe
		2,850 ft	36-in. diameter RCP pipe
		860 ft	30-in. diameter RCP pipe
		790 ft	24-in. diameter RCP pipe
2	Demolition of outfalls	NA	Outfalls to be consolidated to two outfalls at Outfall #2 and #6 locations

Notes:
- Proposed piping includes required joints, fittings, and supports as needed
- Consolidated outfalls include single conduits with a diameter of 54 in

Table 4. Proposed Infrastructure Requirements: Alternative 4

No.	Infrastructure Improvements	Quantity	Comments
1	Pump station with four pumps at design capacity of 50 cfs	1	Proposed pump station to redirect beach outfall flows to Mooring's Bay
2	Piping infrastructure	4,800 ft	60-in. diameter RCP for main pipe
		820 ft	54-in. diameter RCP pipe
		390 ft	48-in. diameter RCP pipe
		1,880 ft	42-in. diameter RCP pipe
		2,850 ft	36-in. diameter RCP pipe
3	Demolition of outfalls	NA	Outfalls to be redirected to Mooring's Bay

Notes:
Proposed piping includes required joints, fittings, and supports as needed.
Force main from pump station to Moorings Bay has a diameter of 60 in.

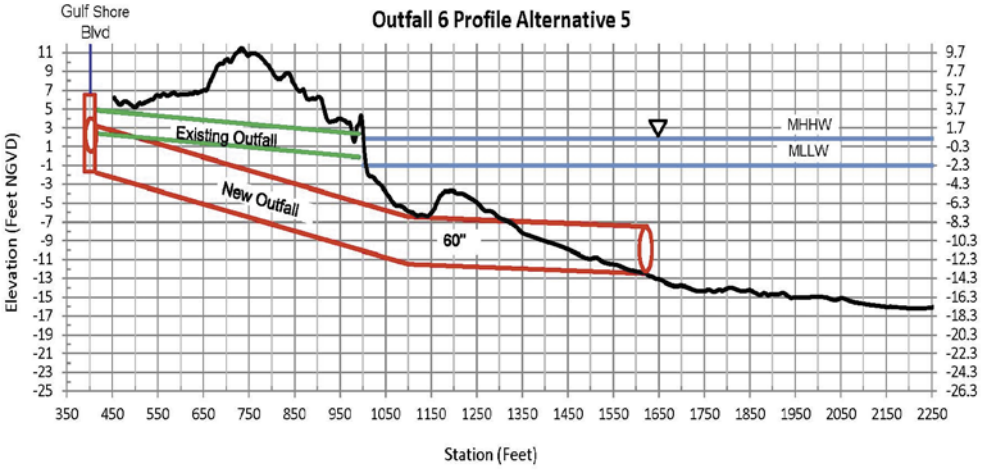

Figure 4. Outfall #6 Profile (Alternative 5)

Alternative 4: Redirection of Beach Outfall Flows via Pump Station to Alternate Location

The City's beach outfall Alternative 4 involves redirection of flow from beach Outfalls #2 through #8 to Moorings Bay via a pump station. The proposed pump station would receive stormwater from the outfalls via gravity flow. A wet well will be integrated with storage at the pump station location. The pump station is assumed to be sized to maintain the existing level of service during the design storm event (five-year, 24-hour) with no overflow. Flows above the design storm event would result in street flooding. In order to maintain the existing or improved level of service, three pumps, with a design capacity of 50 cfs, are required at the proposed pump station. A fourth pump with the same design capacity is recommended to serve as a standby pump.

A new force main is required to carry flow from the proposed pump station to Mooring's Bay and is recommended to be 60 in. in diameter and approximately 4,600 ft in length. The length of the force main was determined based on a conceptual path that was assumed to be practical to carry flow from the proposed pump station to Mooring's Bay. It should be noted that the length of the force main might change depending on the route chosen during final design of the force main. Two options could be considered for sizing of the proposed force main discharging into Moorings Bay: a single 60-in. force main or two 42-in. force mains. Table 4 presents the proposed infrastructure improvements required for implementation of Alternative 4.

Alternative 5: Consolidation of Beach Outfalls Into Single Outfall Buried Deeper and Further Into Gulf of Mexico (Subaqueous Outfalls)

The City's beach outfall Alternative 5 involves consolidation of existing beach outfalls into one; the consolidated outfall will be buried deeper and extended further into the Gulf. Flow

Table 5. Proposed Infrastructure Requirements: Alternative 5

No.	Infrastructure Improvements	Quantity	Comments
1	Pump station with four pumps at design capacity of 50 cfs	1	Proposed pump station to pump to consolidated outfall
2	Piping infrastructure	1,410 ft	60-in. diameter RCP force main pipe
		820 ft	54-in. diameter RCP pipe
		390 ft	48-in. diameter RCP pipe
		1,880 ft	42-in. diameter RCP pipe
		2,850 ft	36-in. diameter RCP pipe
3	Demolition of outfalls	NA	Flow from the outfalls to be consolidated to one outfall at the location of Outfall #6

Notes:

- Proposed piping includes required joints, fittings, and supports as needed.
- Consolidated outfalls include single conduits with a diameter of 60 in.

from the outfalls is recommended to be consolidated to the beach outfall and different locations could be selected for the consolidated beach outfall. The LiDAR data related to this project were considered in the selection of location of the consolidated outfall; the Outfall #6 location was recommended for the consolidated outfall under this alternative and the existing discharge outfalls will be removed. Outfall #6 will be removed and replaced with a larger pipe that is buried deeper and is extended further into the Gulf. The concept profile for Outfall #6 is shown in Figure 4.

A pump station is recommended to pump flows from the outfalls to the proposed consolidated outfall at the Outfall #6 location. In order to maintain the existing or improved level of service, three pumps, with a design capacity of 50 cfs, are required at the proposed pump station. A fourth pump with the same design capacity is recommended to serve as a standby pump. The proposed pump station would receive stormwater runoff from outfalls via gravity flow and then pump into the Gulf.

Table 5 presents the proposed infrastructure improvements required for implementation of Alternative 5.

Cost Estimates

The following Preliminary Opinion of Probable Construction Cost is based on preliminary price quotes from equipment vendors. The assumptions that were made during conceptual cost estimating are:

- Estimates were compiled using available 2012 cost data.
- Labor estimates were compiled based on consultation with marine contractors.
- Installations on land assume multiple crews performing work sections in parallel.
- Work is based on a 150-ton barge crane with mudhog pumps for jetting pipe into place.
- A spud barge for materials is included as a staging platform.
- Work less than 100 ft from shore is assumed to be performed using sheeting and a land based crane.
- Marine work estimates can vary significantly from actual costs if severe weather impacts construction efforts.

Table 6. Summary of Costs for Proposed Alternatives

Alternative #	Description	Total Estimated Cost
1	Integration of beach outfalls with County's planned beach renourishment project	$575,204
2	Integration of beach outfalls with ASR system at WWTP	$11,312,937
3	Consolidation of beach outfalls into two outfalls with a single conduit with a diameter of 54 in.	$3,980,871
	Consolidation of beach outfalls into two outfalls with two conduits each with a diameter of 42 in.	$4,677,246
4	Redirection of beach outfall flows via pump station to Mooring's Bay through a single force main with a diameter of 60 in.	$10,538,499
	Redirection of beach outfall flows via pump station to Mooring's Bay through two force mains each with a diameter of 42 in.	$10,692,675
5	Consolidation and extension of beach outfalls deeper and further into Gulf of Mexico (subaqueous outfalls) with 60-in. force main discharge outfall.	$8,538,141
	Consolidation and extension of beach outfalls deeper and further into Gulf of Mexico (subaqueous outfalls) with two 60-in. gravity discharge outfalls.	$9,528,561

Table 6 provides the preliminary opinion of probable construction cost for the proposed alternatives.

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Table 7. Evaluation of Proposed Alternatives

Alternatives	Goals & Objectives	Benefits	Burdens
Alternative 1: Integration of beach outfalls with County's planned beach renourishment project	☐ Reduce beach erosion ☐ Reduce impacts to turtle nesting habitat ☐ Provide lateral beach access ☐ Reduce impacts to water quality ☐ Improve aesthetics	• Implementation of this alternative is easy and requires less capital investments when compared to other alternatives. • The City will be in compliance with County's beach renourishment project. • Meets or improves existing level of service	• Only partially satisfies FDEP concerns. • Does not meet all the City's goals and objectives. • Bigger storm events (bigger than five-year, 24-hour storm event) still could result in street flooding.
Alternative 2: Integration of beach outfalls with aquifer storage and recovery (ASR) system	☒ Reduce beach erosion ☒ Reduce impacts to turtle nesting habitat ☒ Provide lateral beach access ☒ Reduce impacts to water quality ☒ Improve aesthetics	• Satisfies FDEP concerns and meets City's goals and objectives to some extent. • 2-mgd of permitted capacity is available with City's ASR system. • Improves level of service of the system.	• Uncertainties related to operational testing results. • Only 2-mgd of beach outfall flow (very low capacity compared to the five-year, 24-hour storm peak flow) could be sent to ASR and the rest of the flow will be discharged to ocean. • Construction of force main and ASR wells includes significant capital costs. • Installation of force mains through public roads might pose a challenge. • Construction of a pump station in residential neighborhood and operation and maintenance of pump station is an added burden. • Operation and maintenance of pump station in private golf course is a burden.
Alternative 3: Consolidation of beach outfall pipes	☒ Reduce beach erosion ☒ Reduce impacts to turtle nesting habitat ☒ Provide lateral beach access ☒ Reduce impacts to water quality ☒ Improve aesthetics	• Satisfies FDEP concerns and meets City's goals and objectives to reasonable extent. • Operation and maintenance of two outfalls is easy compared to nine beach outfalls.	• Compromises level of service to certain extent. • Installation of big diameter pipes might pose a challenge. • Bigger storm events (bigger than five-year, 24-hour storm event) could result in street flooding. • Uncertainties related to operation and maintenance of deep ocean outfalls.
Alternative 4: Redirection of beach outfall flows via pump station to Mooring's Bay	☒ Reduce beach erosion ☒ Reduce impacts to turtle nesting habitat ☒ Provide lateral beach access ☒ Reduce impacts to water quality ☒ Improve aesthetics	• Satisfies FDEP concerns and meets City's goals and objectives to greater extent. • Stormwater discharges to ocean can be eliminated completely. • Flushing and oxygenation of Mooring's Bay. • Improves level of service of the system.	• Installation of force mains through public roads might pose a challenge. • Bigger storm events (bigger than five-year, 24-hour storm event) could result in street flooding. • Construction of a pump station in residential neighborhood and operation and maintenance of pump station is an added burden. • Permitting challenges • Impacts Mooring's Bay pollutant loading.
Alternative 5: Consolidation and extension of beach outfalls deeper and further into Gulf of Mexico (subaqueous outfalls)	☒ Reduce beach erosion ☒ Reduce impacts to turtle nesting habitat ☒ Provide lateral beach access ☒ Reduce impacts to water quality ☒ Improve aesthetics	• Satisfies FDEP concerns and meets City's goals and objectives to reasonable extent. • Operation and maintenance of one outfall is easy compared to nine beach outfalls. • Pump station option improves level of service of the system.	• Compromises level of service to certain extent with gravity main option. • Bigger storm events (bigger than five-year, 24-hour storm event) could result in street flooding. • Construction of a pump station in residential neighborhood and operation and maintenance of pump station is an added burden. • Uncertainties related to operation and maintenance of deep ocean outfalls.

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The proposed five alternatives were further analyzed to determine the extent to which they achieve identified goals and objectives, namely:

1. Reduce beach erosion
2. Reduce impacts to turtle nesting habitat
3. Provide lateral beach access
4. Reduce impacts to water quality
5. Improve aesthetics

Table 7 presents such analysis of the proposed beach outfall alternatives. The table also lists potential benefits and burdens associated with each alternative.