pompano beach
Florida's Warmest Welcome

DEVELOPMENT SERVICES
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ADMINISTRATIVE MEMORANDUM NO. 24-036

TO: Greg Harrison, City Manager
VIA: Brian Donovan, Assistant City Manager
VIA: David L. Recor, ICMA-CM, Development Services Director
FROM: Jean E. Dolan, AICP, CFM, Principal Planner
DATE: May 15, 2024

Staff is proposing amendments to Chapter 152 to create standards for stormwater retention for single-family and duplex construction. Currently, the only retention standard for this type of development relates to the percent pervious area required by the zoning code. When neighbors complain about run-off from neighboring properties, there are no drainage plans on file that define how much water was intended to be managed on the offending property and how it was to be maintained on site. This leaves staff with no way to evaluate or address the complaint.

All development types other than single-family and duplex construction must undergo the County's drainage permitting process, however, single-family and duplex housing is not covered by the County's stormwater permitting requirements. Given the higher finished floor elevations applicable to new construction and substantial improvement that will be in effect on July 31, 2024, complaints about stormwater runoff onto neighboring properties are anticipated to become commonplace. The proposed changes to Chapter 152, therefore, create a requirement for a stormwater management plan for single-family and duplex construction to be submitted and reviewed at the time of building permit to ensure the minimum stormwater retention requirement is met and the site is property graded to reduce flooding of neighboring properties.

Chen Moore and Associates (the same firm that did our Stormwater Master Plan) was hired to conduct an engineering study to:

- Determine the volume of on-site retention that can be reasonably accommodated within stormwater retention areas and/or swales on typical residential parcels with the minimum pervious area requirements from the City's Zoning Code for single family and duplex parcels.
- Establish the assumed parameters for any stormwater retention areas and/or swales required to retain stormwater runoff on-site at these single family and duplex parcels.
- Establish the assumed parameters for any retaining walls that may be required along property lines to retain stormwater runoff on-site at these single family and duplex parcels.
- Prepare a guidance document establishing the parameters for preparing future Stormwater Management Plans for single-family and duplex construction.

The study concluded that it would be reasonably feasible for most single family or duplex parcels to be configured to retain 1.0 inch of rainfall on-site. The retention of 1-inch of stormwater runoff would be consistent with the SFWMD and BCEPGM permit criteria to provide on-site stormwater retention for water quality treatment purposes on other parcel types that are required to obtain a surface water license from BCEPGM.

Individual single family and duplex parcels to be developed or redeveloped will need to be evaluated on a case-by-case basis to determine the most efficient configuration for stormwater retention areas, swale areas, and/or retaining walls to be implemented to retain 1-inch of stormwater runoff on-site. Based on the evaluation,

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stormwater retention areas and/or swale areas would need to be distributed among the side yards, front yard, and rear yard of each single family and duplex parcel. The implementation of a perimeter berm or retaining walls along the property lines may be required on some parcels to ensure the stormwater retention areas and/or swale areas provide sufficient storage volume to retain 1.0 inch of rainfall on-site. In locations where the implementation of a perimeter berm or retaining walls along the property lines are not viable options, other potential alternatives will have to be investigated, such as implementing on-site stormwater storage chambers or creating structural underground stormwater storage.

The changes to Chapter 152 that result from the above conclusion are attached along with the full study performed by Chen Moore and Associates. The Guidance document to assist future Applicants for single-family and duplex building permits to prepare the required stormwater management plan is also attached.

JED

Attachments

Floodplain Management Regulations – Section 152.31(F)
Engineering Guidance Document

The City of Pompano Beach has updated their Floodplain Management Regulations to require sufficient on-site retention for stormwater runoff for new development and/or redevelopment within single family parcels and duplex parcels. The City Code has been updated to include Section 152.31(F), which establishes the following Floodplain Management Regulations for new development and/or redevelopment within single family parcels and duplex parcels:

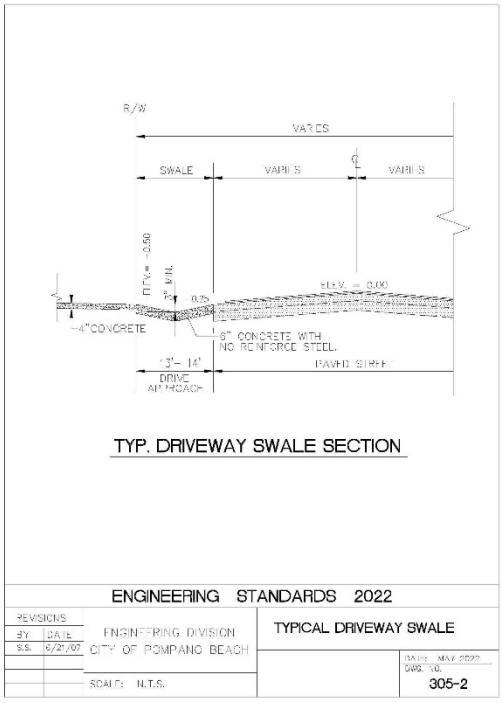
(F) Single Family and Duplex Residential Stormwater Management Performance Standards.
- *(1) Applicability. The standards of this subsection shall apply to new construction or substantial improvements to single family and duplex residential projects with a lot area under one acre in size.*
- *(2) Stormwater Management Plan Required. To implement the requirements herein, a stormwater management plan and site drainage calculations shall be prepared by a Professional Engineer (P.E.) licensed by the State of Florida that demonstrates that the on-site drainage facilities provide at least the minimum retention storage volume of one inch times the total area of the parcel. The stormwater runoff water shall be diverted to a stormwater conveyance other than the City's stormwater management system per Section 53.13(A)(1). The site shall be graded in a manner to drain stormwater runoff away from foundations.*
- *(3) For single family parcels and duplex parcels, the site must retain the volume of stormwater runoff that equates to one inch times the total area of the parcel. Retention must be adequate to ensure the inch of retention with:*
  - *(a) No runoff from front yard area to the street or adjacent property.*
  - *(b) No runoff from side yard areas to adjacent properties.*
  - *(c) No runoff from backyard area to adjacent properties, Intracoastal Waterway, or adjacent canal.*
  - *(d) No runoff into the right-of-way or street from driveways.*
- *(4) Maintenance of Privately Owned Stormwater Management Systems.*
  - *(a) Should the privately owned stormwater management system fail to function as designed and intended, the owner or maintenance entity shall take appropriate corrective measures to restore and ensure proper operation of the system.*
  - *(b) Inspections may be performed by City officials when reasonably necessary to carry out the purposes of this section.*
  - *(c) This section may be enforced by any means legally available to the city.*

During the preparation of any stormwater management plan and site drainage calculations for any new development and/or redevelopment within single family parcels and duplex parcels, the Professional Engineer shall use the following design assumptions when determining the on-site storage volume provided for stormwater runoff within any on-site stormwater facilities:

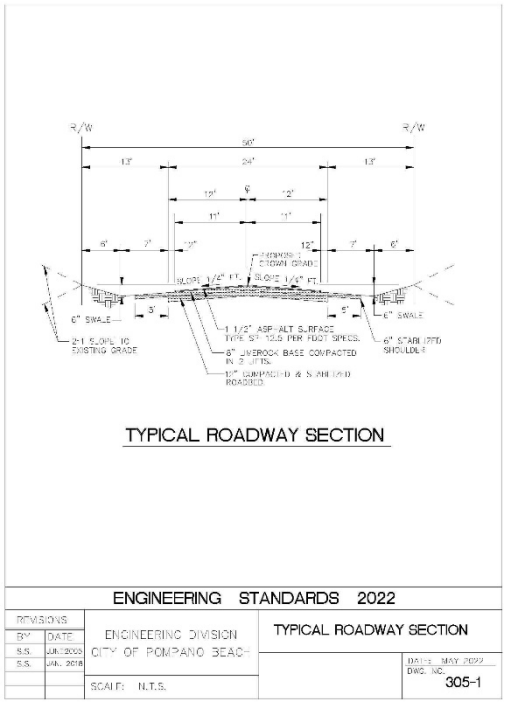
- Groundwater Elevation – The site drainage calculations shall use a groundwater elevation defined for the site location within the Broward County Future Conditions Groundwater Elevation Map (Plate WM 2.1 Future Conditions), which is referenced in the Broward County Code of Ordinances (Section 27-200). The current version of the Future Conditions Groundwater Elevation Map can be found on the County's website at: https://www.broward.org/Environment/WaterPrograms/Pages/FutureConditionsMapSeries.aspx.
- Maximum Side Slopes – During the development of the stormwater management plan, any proposed on-site dry retention areas or swale areas shall have a maximum side slope of 4 Horizontal : 1 Vertical.
- Minimum Bottom Elevation – During the development of the stormwater management plan, any proposed on-site dry retention areas or swale areas shall have the bottom elevation set at least 12 inches

above groundwater elevation defined for the site location within the Broward County Future Conditions Groundwater Elevation Map (Plate WM 2.1 Future Conditions).

- Perimeter Elevation – During the preparation of the site drainage calculations, the lowest top of bank elevation around the perimeter of each proposed on-site dry retention area or swale area shall be used to determine the storage volume provided for stormwater runoff. No storage volume can be considered above the lowest top of bank elevation around the perimeter of each proposed on-site dry retention area or swale area.
- Ground Surface Type – During the preparation of the site drainage calculations, on-site storage volume provided for stormwater runoff can only be provided within on-site dry retention areas or swale areas with a pervious ground surface, such as grass or landscaped ground cover. Any on-site storage volume provided in areas with impervious ground surface, such as asphalt pavement, concrete, or pavers, shall not be considered.
- Soil Storage – During the preparation of the site drainage calculations, a soil storage volume can be assumed below any on-site pervious ground surface areas with grass coverage or landscaped ground coverage according to SFWMD guidelines, which are defined within Section 5.7.4.2 of the SFWMD Environmental Resource Permit Applicants Handbook.
- Exfiltration Trench – During the preparation of the site drainage calculations, on-site storage volume provided for stormwater runoff with proposed exfiltration trenches or french drains shall be determined using the SFWMD formula for exfiltration trench system, which is defined within SFWMD Environmental Resource Permit Applicants Handbook.
- Driveway Connections – Any driveway connections to a public roadway shall be graded to be slightly lower than the existing roadway edge of pavement elevation, which will prevent stormwater runoff from flowing directly from the driveway into the public roadway. The grading of the driveway connection should be configured to divert any stormwater runoff from the driveway into adjacent roadway swales within the public right of way instead of directly into the public roadway according to Drawing 305-1 Typical Roadway Section and Drawing 305-2 Typical Driveway Swale within the City's Engineering Standards 2022, which are displayed below.



TYP. DRIVEWAY SWALE SECTION



TYPICAL ROADWAY SECTION

chen moore and associates

April 10, 2022

City of Pompano Beach
100 West Atlantic Boulevard
Pompano Beach, Florida 33060
ATTN: Jean Dolan, AICP, CFM

Subject: Stormwater Retention Requirements and Design Guidelines Review Technical Memorandum

Dear Ms. Dolan:

On behalf of the City of Pompano Beach (City), Chen Moore and Associates (CMA) conducted a preliminary evaluation of potential changes to stormwater retention requirements and design guidelines for on-site retention and increased finished floor elevations at the single-family and duplex parcels within the City. The 2019 FEMA Coastal Study Flood Map update commenced the statutory 90-day appeal period after publication of the second notice of commencement in the Federal Register on November 24th, 2021, which will establish updated base flood elevations throughout Broward County. The updated Flood Insurance Rate Maps (FIRM) for Broward County will likely become effective sometime in 2022. These updated FIRM maps will establish the minimum requirements for finished floor elevations for any new construction and substantial building improvements throughout Broward County. Within some neighborhoods in the City of Pompano Beach, these updated FIRM maps will require finished floor elevations that are considerably higher than the existing ground surface elevations and/or current finished floor elevations of existing structures on adjacent parcels. Due to these higher finished floor requirements, some new development or substantial building improvements may require the entire parcel to be filled to a higher elevation, which could lead to stormwater runoff flowing from this elevated parcel into adjacent lower private properties and public right of way.

The City wants to evaluate the feasibility of the potential changes to stormwater retention requirements and design guidelines for on-site retention and increased finished floor elevations at the single-family and duplex parcels within the City. The intent of this evaluation is to verify the feasibility of the potential changes to stormwater retention requirements and design guidelines for on-site retention and increased finished floor elevations at the single-family and duplex parcels within the City. The primary purpose of this evaluation is summarized below:

- Estimate the volume of on-site retention that can be reasonably accommodated within stormwater retention areas and/or swales on typical residential parcels with ground coverage requirements from the City's Zoning Code for single family and duplex parcels.
- Establish the assumed parameters for any stormwater retention areas and/or swales required to retain stormwater runoff on-site at these single family and duplex parcels.
- Establish the assumed parameters for any retaining walls that may be required along property lines to retain stormwater runoff on-site at these single family and duplex parcels.
- Investigate any structural methods for providing additional storage capacity required to retain stormwater runoff on-site at these single family and duplex parcels.
- Consider whether finished floor elevations could be set even higher than required to prepare for future sea level rise.

This memorandum is intended to summarize the evaluation the stormwater retention requirements initially considered by the City for on-site retention and increased finished floor elevations at the single-family and duplex parcels and to provide any recommendations on more feasible stormwater retention requirements.

Sample Parcel Selections

CMA selected nine sample residential parcels throughout the City limits that are intended to be representative of the typical single family parcels and duplex parcels within the City. These sample residential parcels were selected to be among the Single-Family Residence (RS-1, RS-2, and RS-3) zoning designations or under the Two-Family Residential (RD-1) zoning designation. These sample residential parcels were selected to be distributed throughout the City limits to obtain a representative sample. For example, at least one sample parcel is located in each of the five Commission Districts within the City. Due to the variation in ground surface elevations throughout the City limits, these sample residential parcels were selected to include parcels with low elevations, average elevations, and high elevations along with the relevant flood zone designations throughout the City. These sample parcels were also selected to have a variety of configurations, such as being currently vacant, having an existing residential structure, being adjacent to an existing waterway, being a corner lot, having adjacent residential parcels on three sides, and/or having atypical shapes. Please refer to the map exhibit for each sample residential parcel, which summarize the parcel parameter and are included in Appendix A.

Future Development Assumptions

CMA developed assumptions on the future buildout condition of each sample residential parcel. Any existing buildings on these sample residential parcels was ignored. Each sample residential parcel was assumed to be developed or redeveloped to the maximum extent allowed under the setback requirements and ground coverage requirements defined under Article 3 of the City's Zoning Code. The zoning requirements for the relevant zoning designation of RS-1, RS-2, RS-3, and RD-1 are enclosed in Appendix B of this memorandum and are summarized within the table below:

Residential Zoning Requirements				
Requirement	**RS-1**	**RS-2**	**RS-3**	**RD-1**
Front Setback (feet)	35	25	25	25
Rear Setback (feet)	20	20	15	15
Street Side Setback (feet)	18	15	15	18
Waterway or Canal Setback (feet)	25	25	25	25
Interior Side Yard Setback (feet)	10	7.5	7	8
Minimum Pervious Area (%)	30	30	30	30

For this analysis, CMA assumed that the sample residential parcel would be developed and/or redeveloped to maximize proposed building areas while meeting the minimum setback requirements from all lot lines as defined by the City's Zoning Code. A proposed driveway width and area were assumed using the criteria in the Minimum Standards Exhibit from the Broward County Administrative Code, which states that the driveway width may not be greater than 30 percent of the front lot width. The driveway criterion was also applied to circular driveways where the driveway width would be half of a typical straight driveway since it borders the front lot line twice. A breakdown of the assumed ground coverages at each sample residential parcel is summarized within the table below:

Assumed Ground Coverage (% of Total Lot Area)					
Sample Parcel	**Zoning Code**	**Building**	**Driveway**	**Pervious**	**Total Area**
A	RS-2	56%	4%	40%	20,304
B	RS-2	45%	11%	44%	14,000
C	RS-2	53%	6%	42%	14,380

Assumed Ground Coverage (% of Total Lot Area)					
Sample Parcel	**Zoning Code**	**Building**	**Driveway**	**Pervious**	**Total Area**
D	RS-2	44%	10%	46%	8,250
E	RS-3	47%	7%	46%	6,182
F	RS-3	46%	7%	47%	6,000
G	RS-2	51%	7%	42%	10,800
H	RS-3	51%	7%	42%	8,400
I	RD-1	53%	6%	41%	8,840

Feasibility Evaluation of Potential Stormwater Retention Requirements

The City has requested that CMA evaluate these sample residential parcels to determine the feasibility of retaining 2.8 inches of rainfall on-site. This rainfall amount is equivalent to the 3-year / 1-hour design storm interpolated from the 2-year/1-hour and 5-year/1-hour design storms defined in the 1961 Department of Commerce's Technical Paper No. 40: Rainfall Frequency Atlas of the United States. CMA multiplied the 2.8 inches of rainfall with the total area of each sample residential parcel to determine the total volume of stormwater runoff that would need to be retained on-site under this potential design requirement. A breakdown of the stormwater runoff that would need to be retained on-site under at each sample residential parcel this potential design requirement is summarized within the table below:

Water Quantity Storage Requirements					
Sample Project	**Sample Project Areas (acres)**				**Required Stormwater Storage Volume (ac-in)**
	Total Area	**Total Building Area**	**Total Driveway Area**	**Total Pervious Area**	
A	0.47	0.26	0.02	0.19	1.31
B	0.32	0.14	0.04	0.14	0.90
C	0.33	0.17	0.02	0.14	0.92
D	0.19	0.08	0.02	0.09	0.53
E	0.14	0.07	0.01	0.07	0.40
F	0.14	0.06	0.01	0.06	0.39
G	0.25	0.13	0.02	0.10	0.69
H	0.19	0.10	0.01	0.08	0.54
I	0.20	0.11	0.01	0.08	0.57

CMA evaluated the implementation of various alternatives to retain stormwater runoff on-site at these sample residential parcels without any significant structural improvements. The proposed FEMA base flood elevations were used to establish the finish floor elevation at each sample residential parcel. Available LiDAR elevation data was used to establish the boundary conditions along each property line within each sample residential parcel. The Broward County Future Groundwater Table Elevation Map was used to establish the bottom elevation for any stormwater retention areas and/or swale areas on each sample residential parcel, which were set to be at least 12 inches above the relevant future groundwater table elevation. CMA evaluated whether stormwater retention areas and/or swale areas with various design parameters can provide sufficient storage capacity at each of the sample residential parcels. Please refer to the detailed water quantity inventory for each alternative included in Appendix C.

Alternative 1 – Triangular Swales

CMA incorporated typical triangular shaped swale storage areas along the side yards only within each sample residential parcel. The swale storage areas lengths were assumed to be along the entire length of the side property lines but were not located within rear yards and front yards. The swale storage areas were assumed to have side slope set at a 4H:1V, which slope down from the assumed finished floor elevations for the proposed building and slope down from the existing elevations along the side property lines. The finished floor elevations were set to match the proposed FEMA base flood elevation defined for each sample residential parcel. The perimeter elevation for each sample residential parcel was conservatively set at the lowest perimeter elevation to avoid runoff into adjacent properties, right of way, or canals. The total volume of stormwater runoff that could be retained in each swale storage area along the side yards at each sample residential parcel was calculated and compared against the total volume required under the potential design requirement of retaining 2.8 inches of rainfall on-site. Based on our evaluation, the average storage available in triangular swales within side yards only is estimated to provide approximately 0.02 ac-in in storage volume, which would be equivalent to approximately 0.11 inches of rainfall. The minimal storage capacity is largely due to the short setback width requirements and the significant elevation difference between the base flood elevations and lowest perimeter elevations at each sample residential parcel. The storage volume provided within triangular swales within the side yards only at each sample residential parcel is summarized in the table below:

Storage Volume Comparison (Triangular Swales – Side Yard Only)							
					Triangular Swale Alternative		
Sample Parcel	Future Groundwater Elevation (feet NAVD)	2021 Base Flood Elevation (feet NAVD)	Required Stormwater Storage Volume (ac-in)	Parcel Line Location	Storage Volume Provided (ac-in)	Storage Volume Provided (ac-in)	Equivalent Rainfall Depth Provided (in)
A	1.50	8.00	1.31	North	0.00	0.00	0.00
				South	0.00		
B	1.00	7.00	0.90	South	0.02	0.03	0.09
				North	0.01		
C	2.00	7.00	0.92	North	0.00	0.00	0.00
				South	0.00		
D	1.50	7.00	0.53	East	0.01	0.01	0.05
				West	0.00		
E	4.50	12.00	0.40	East	0.01	0.02	0.14
				West	0.02		
F	4.50	13.00	0.39	East	0.01	0.01	0.07
				West	0.00		
G	1.50	7.00	0.69	East	0.05	0.11	0.44
				West	0.05		
H	3.00	12.00	0.54	East	0.00	0.00	0.00
				West	0.00		
I	3.00	15.00	0.57	East	0.01	0.04	0.20
				West	0.02		

CMA also incorporated typical triangular shaped swale storage areas within available portions of the front yards, rear yards, and side yards within each sample residential parcel. The swale storage areas lengths were assumed to be along the entire length of the side property lines but were assumed to only be within available portions of the rear yards and front yards. Based on our evaluation, the average storage available in triangular swales within side, front, and rear yards is estimated to provide approximately 0.26 ac-in in storage volume, which would be equivalent to approximately 1.22 inches of rainfall. The minimal storage

capacity is largely due to the short setback width requirements and the significant elevation difference between the base flood elevations and lowest perimeter elevations at each sample residential parcel. The storage volume provided within triangular swales within the side yards only at each sample residential parcel is summarized in the table below:

Storage Volume Comparison (Triangular Swales – All Available Areas)						
Sample Project	**Future Groundwater Elevation (feet NAVD)**	**2021 Base Flood Elevation (feet NAVD)**	**Required Stormwater Storage Volume (ac-in)**	**Parcel Line Location**	**Triangular Swale Alternative**	
					Storage Volume Provided (ac-in)	**Equivalent Rainfall Depth Provided (in)**
A	1.50	8.00	1.31	Front North Rear South	0.06	0.13
B	1.00	7.00	0.90	Front South Rear North	0.79	2.46
C	2.00	7.00	0.92	Front North Rear South	0.00	0.00
D	1.50	7.00	0.53	Front East Rear West	0.30	1.58
E	4.50	12.00	0.40	Front East Rear West	0.28	1.97
F	4.50	13.00	0.39	Front East Rear West	0.28	2.03
G	1.50	7.00	0.69	Front East Rear West	0.14	0.56
H	3.00	12.00	0.54	Front East Rear West	0.17	0.88
I	3.00	15.00	0.57	Front East Rear West	0.29	1.43

Based on our analysis, none of the sample residential parcels can retain the 2.8 inches of rainfall within typical triangular swale areas. The low ground elevations along the property lines at each sample residential parcels were the primary cause for the potential triangular swale areas providing insufficient storage capacity for retaining stormwater runoff within each parcel. The storage capacity of these potential triangular swale areas could be increased by raising the perimeter elevation around each sample residential

parcel, which could be accomplished by installing a berm or retaining walls along the property lines, particularly along the side property lines. The implementation of a perimeter berm or retaining wall along the relevant property lines would increase the volume of stormwater runoff retained within each parcel within swale areas.

Alternative 2 – Trapezoidal Swales

CMA incorporated typical trapezoidal shaped swale storage areas along the side yards only within each sample residential parcel. The swale storage areas lengths were assumed to be along the entire length of the side property lines but were not located within rear yards and front yards. The swale storage areas were assumed to have side slope set at a 4H:1V, which slope down from the assumed finished floor elevations for a proposed building and down from the existing elevations along a side property lines to a flat bottom swale. The finished floor elevations were set to match the proposed FEMA base flood elevation defined for each sample residential parcel. The perimeter elevation for each sample residential parcel was conservatively set at the lowest perimeter elevation to avoid runoff into adjacent properties, right-of-way, or canals. The total volume of stormwater runoff that could be retained in each swale storage area along the side yards at each sample residential parcel was calculated and compared against the total volume required under the potential design requirement of retaining 2.8 inches of rainfall on-site. Based on our evaluation, the average storage available in trapezoidal swales within side yards only is estimated to provide approximately 0.02 ac-in in storage volume, which would be equivalent to approximately 0.11 inches of rainfall. The minimal storage capacity is largely due to the short setback width requirements and the significant elevation difference between the base flood elevations and lowest perimeter elevations at each sample residential parcel. The storage volume provided within trapezoidal swales within the side yards only at each sample residential parcel is summarized in the table below:

Storage Volume Comparison (Trapezoidal Swales – Side Yard Only)

Sample Parcel	Future Groundwater Elevation (feet NAVD)	2021 Base Flood Elevation feet NAVD	Required Stormwater Storage (ac-in)	Parcel Line Location	Trapezoidal Swale Alternative		
					Storage Volume Provided (ac-in)	Storage Volume Provided (ac-in)	Equivalent Rainfall Depth Provided (in)
A	1.50	8.00	1.31	North	0.00	0.00	0.00
				South	0.00		
B	1.00	7.00	0.90	South	0.02	0.03	0.09
				North	0.01		
C	2.00	7.00	0.92	North	0.00	0.00	0.00
				South	0.00		
D	1.50	7.00	0.53	East	0.01	0.01	0.05
				West	0.00		
E	4.50	12.00	0.40	East	0.01	0.02	0.14
				West	0.01		
F	4.50	13.00	0.39	East	0.01	0.01	0.07
				West	0.00		
G	1.50	7.00	0.69	East	0.05	0.11	0.44
				West	0.05		
H	3.00	12.00	0.54	East	0.00	0.00	0.00
				West	0.00		
I	3.00	15.00	0.57	East	0.01	0.03	0.15
				West	0.02		

CMA also incorporated typical trapezoidal shaped swale storage areas within available portions of the front yards, rear yards, and side yards within each sample residential parcel. The swale storage areas lengths were assumed to be along the entire length of the side property lines but were assumed to only be within available portions of the rear yards and front yards. Based on our evaluation, the average storage available in trapezoidal swales within side, front, and rear yards is estimated to provide approximately 0.20 ac-in in storage volume, which would be equivalent to approximately 0.94 inches of rainfall. The storage volume provided within trapezoidal swales throughout each sample residential parcel is summarized in the table below:

Storage Volume Comparison (Trapezoidal Swales - All Available Areas)							
Sample Parcel	**Future Groundwater Elevation (feet NAVD)**	**2021 Base Flood Elevation feet NAVD**	**Required Stormwater Storage (ac-in)**	**Parcel Line Location**	**Storage Volume Provided (ac-in)**	**Trapezoidal Swale Alternative**	
						Storage Volume Provided (ac-in)	**Equivalent Rainfall Depth Provided (in)**
A	1.50	8.00	1.31	Front	0.04	0.07	0.15
				North	0.00		
				Rear	0.02		
				South	0.00		
B	1.00	7.00	0.90	Front	0.00	0.54	1.68
				South	0.02		
				Rear	0.76		
				North	0.01		
C	2.00	7.00	0.92	Front	0.00	0.00	0.00
				North	0.00		
				Rear	0.00		
				South	0.00		
D	1.50	7.00	0.53	Front	0.00	0.23	1.21
				East	0.01		
				Rear	0.29		
				West	0.00		
E	4.50	12.00	0.40	Front	0.21	0.19	1.34
				East	0.01		
				Rear	0.05		
				West	0.02		
F	4.50	13.00	0.39	Front	0.14	0.22	1.60
				East	0.01		
				Rear	0.13		
				West	0.00		
G	1.50	7.00	0.69	Front	0.03	0.14	0.56
				East	0.05		
				Rear	0.00		
				West	0.05		
H	3.00	12.00	0.54	Front	0.13	0.15	0.78
				East	0.00		
				Rear	0.04		
				West	0.00		
I	3.00	15.00	0.57	Front	0.17	0.24	1.18
				East	0.01		
				Rear	0.09		
				West	0.02		

Based on our analysis, none of the sample residential parcels can retain the 2.8 inches of rainfall within typical trapezoidal swale areas. The low ground elevations along the property lines at each sample residential parcels were the primary cause for the potential trapezoidal swale areas providing insufficient storage capacity for retaining stormwater runoff within each parcel. The storage capacity of these potential trapezoidal swale areas could be increased by raising the perimeter elevation around each sample residential

parcel, which could be accomplished by installing a berm or retaining walls along the property lines, particularly along the side property lines. The implementation of a perimeter berm or retaining wall along the relevant property lines would increase volume of stormwater runoff retained within each parcel within swale areas.

Alternative 3

CMA incorporated typical trapezoidal shaped swale storage areas along the side yards only within each sample residential parcel along with the implementation a perimeter berm or retaining wall along the side property lines. The swale storage areas lengths were assumed to be along the entire length of the side property lines but were not located within rear yards and front yards. The swale storage areas were assumed to have a side slope set at a 4H:1V, which slope down from the assumed finished floor elevations for the proposed building to a flat swale bottom that extends to the side property lines. The finished floor elevations were set to match the proposed FEMA base flood elevation defined for each sample residential parcel. The total volume of stormwater runoff that could be retained in each swale storage area along the side yards at each sample residential parcel was calculated and compared against the total volume required under the potential design requirement of retaining 2.8 inches of rainfall on-site. Based on our evaluation, the average storage available in trapezoidal swales within side yards only is estimated to provide approximately 0.28 ac-in in storage volume, which would be equivalent to approximately 1.67 inches of rainfall. The minimal storage capacity is largely due to the short setback width requirements. The storage volume provided within trapezoidal swales within the side yards only at each sample residential parcel along with a perimeter berm or retaining wall along the side property lines is summarized in the table below:

Storage Volume Comparison (Trapezoidal Swales with Retaining Walls – Side Yard Only)

Sample Parcel	Future Groundwater Elevation (feet NAVD)	2021 Base Flood Elevation feet NAVD	Required Stormwater Storage Volume (ac-in)	Parcel Line Location	Retaining Wall Alternative	
					Storage Volume Provided (ac-in)	Equivalent Rainfall Depth Provided (in)
A	1.50	8.00	1.31	North South	0.31	0.67
B	1.00	7.00	0.90	South North	0.09	0.28
C	2.00	7.00	0.92	North South	1.12	3.39
D	1.50	7.00	0.53	East West	0.18	0.95
E	4.50	12.00	0.40	East West	0.15	1.06
F	4.50	13.00	0.39	East West	0.16	1.16
G	1.50	7.00	0.69	East West	0.11	0.44
H	3.00	12.00	0.54	East West	0.22	1.14
I	3.00	15.00	0.57	East West	0.23	1.13

CMA also incorporated typical trapezoidal shaped swale storage areas within available portions of the front yards, rear yards, and side yards within each sample residential parcel along with the implementation a perimeter berm or retaining wall along the side property lines. The swale storage areas lengths were

assumed to be along the entire length of the side property lines but were assumed to only be within available portion of the rear yards and front yards. Based on our evaluation, the average storage available in trapezoidal swales within side, front, and rear yards is estimated to provide approximately 1.59 ac-in in storage volume, which would be equivalent to approximately 5.56 inches of rainfall. The storage volume provided within trapezoidal swales throughout at each sample residential parcel is summarized in the table below:

Storage Volume Comparison (Trapezoidal Swales with Retaining Walls – All Available Areas)						
Sample Parcel	**Future Groundwater Elevation (feet NAVD)**	**2021 Base Flood Elevation feet NAVD**	**Required Stormwater Storage Volume (ac-in)**	**Parcel Line Location**	**Retaining Wall Alternative**	
					Storage Volume Provided (ac-in)	**Equivalent Rainfall Depth Provided (in)**
A	1.50	8.00	1.31	Front North Rear South	4.90	10.5
B	1.00	7.00	0.90	Front South Rear North	2.53	7.9
C	2.00	7.00	0.92	Front North Rear South	2.05	6.2
D	1.50	7.00	0.53	Front East Rear West	1.25	6.6
E	4.50	12.00	0.40	Front East Rear West	0.44	3.1
F	4.50	13.00	0.39	Front East Rear West	0.42	3.0
G	1.50	7.00	0.69	Front East Rear West	1.25	5.0
H	3.00	12.00	0.54	Front East Rear West	0.92	4.8
I	3.00	15.00	0.57	Front East Rear West	0.59	2.9

Based on the evaluation of the sample parcels under the various alternatives noted above, it is not reasonably feasible for single family or duplex parcels to be configured to retain 2.8 inches of rainfall on-site. The amount of on-site stormwater retention is largely dependent on the size and configuration of the individual parcels along with setback requirements. Since most single family or duplex parcels within the City are relatively small and narrow along with limited setback requirements, the volume of stormwater that can potentially be retained within swale areas or retention areas are very limited. Due to the low ground surface elevations and high groundwater table elevations throughout the City, the volume of stormwater that can potentially be retained within underground systems, such as exfiltration and stormwater storage chambers, are also significantly limited. Although the City needs to implement new stormwater retention requirements to reduce the possibility of stormwater runoff flowing from a new single family or duplex home on an elevated parcel into adjacent lower private properties and public right of way, the City intends to implement new stormwater retention requirements that are reasonably feasible at most single family or duplex parcels. Based on our evaluation, the City should consider implementing new stormwater retention requirements that will retain less than 2.8 inches of rainfall on-site.

Broward County Chapter 27 Requirements

South Florida Water Management District (SFWMD) and Broward County Environmental Protection and Growth Management (BCEPGM) are the primary regulatory agencies with jurisdiction over stormwater issues at FLL. Chapter 40E-4 of the Florida Administrative Code (FAC) creates and empowers the SFWMD to regulate all matters related to stormwater management. Chapter 27 – Pollution Control, Article V – Water Resource Management of the Broward County Code of Ordinances similarly empowers the BCEPGM with similar regulatory duties. In general, these regulatory agencies enforce the following primary requirements related to peak discharge and water quality treatment for stormwater runoff:

- Peak discharge from stormwater outfalls during a 25-year/72-hour rainfall event shall not exceed the previously permitted peak discharge according to previous permits from SFWMD and/or BCEPGM or shall not exceed the peak discharge under the pre-development conditions when the site was not previously permitted.
- The retention and detention of stormwater runoff shall be provided on-site for water quality treatment purposes using the following criteria:
    1) The total wet detention volume provided on-site shall equal or exceed one inch of stormwater runoff from the entire site area or 2.5 inches of stormwater runoff from the total impervious ground surface within the site, whichever is greater.
    2) The total dry detention volume provided on-site shall equal or exceed 75% of one inch of stormwater runoff from the entire site area or 75% of 2.5 inches of stormwater runoff from the total impervious ground surface within the site, whichever is greater.
    3) The pretreatment retention volume provided within each site prior to discharging into any master stormwater management system shall equal or exceed 50% of one inch of stormwater runoff from each site or 50% of 2.5 inches of stormwater runoff from the total impervious ground surface within each site, whichever is greater.

Chapter 27 – Pollution Control, Article V – Water Resource Management includes various exemptions from these regulatory requirements related to stormwater management. Individual single family homes or duplexes on parcels less than 2 acres in size and with less than 0.5 acres of isolated wetland impacts are specifically exempted from these regulatory requirements related to stormwater management provided that the construction complies with the requirements of Article XI of Chapter 27. Therefore, the redevelopment of any individual single family or duplex parcel within the City will not be required to obtain a surface water license from Broward County. Although any individual single family or duplex parcels within the City are not required to obtain a Broward County surface water license, the County's stormwater retention

requirements for other parcel types provide some guidance for the potential stormwater retention requirements that the City may consider implementing for the single-family and duplex parcels.

Recommendations of Potential Stormwater Retention Requirements

Based on the evaluation of the sample parcels under the various alternatives noted above, it would be reasonably feasible for most single family or duplex parcels to be configured to retain 1.0 inch of rainfall on-site. The retention of 1-inch of stormwater runoff would be consistent with the SFWMD and BCEPGM permit criteria to provide on-site stormwater retention for water quality treatment purposes on other parcel types that are required to obtain a surface water license from BCEPGM. Due to the reasonable feasibility of retaining 1-inch of rainfall at most single family or duplex parcels along with the consistency with other regulatory criteria related to stormwater retention, the City should consider implementing stormwater retention requirements on new development, redevelopment, and substantial improvements within single family and duplex parcels, which would require 1-inch of rainfall to be retained on-site.

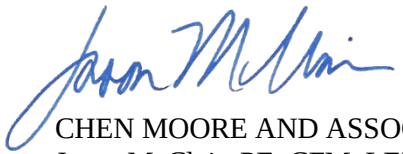
Any individual single family and duplex parcel to be developed or redeveloped will need to be evaluated on a case-by-case basis to determine the most efficient configuration for any stormwater retention areas, swale areas, and/or retaining walls to be implemented to retain 1-inch of stormwater runoff on-site. Based on our evaluation, any stormwater retention areas and/or swale areas would need to be distributed among the side yards, front yard, and rear yard of each single family and duplex parcel to retain 1-inch of rainfall on-site. The implementation of a perimeter berm or retaining walls along the property lines may be required at some parcels to ensure the stormwater retention areas and/or swale areas to provide sufficient storage volume to retain 1.0 inch of rainfall on-site. In locations where the implementation of a perimeter berm or retaining walls along the property lines are not viable options, other potential alternatives will have to be investigated, such as implementing on-site stormwater storage chambers or creating stormwater storage below the proposed building construction.

Conclusion

Based on our evaluation, it is not reasonably feasible to require the retention of 2.8 inches of rainfall on-site within a typical single family and duplex parcel in the City. As an option, the City should consider requiring new development, redevelopment, or substantial improvements on the single-family and duplex parcels within the City to retain 1.0 inch of rainfall on-site. The retention of 1-inch of stormwater runoff would be reasonably feasible at most single-family and duplex parcels within the City and would also be consistent with the SFWMD and BCEPGM permit criteria to provide on-site stormwater retention for water quality treatment purposes on other parcel types that are required to obtain a surface water license from BCEPGM.

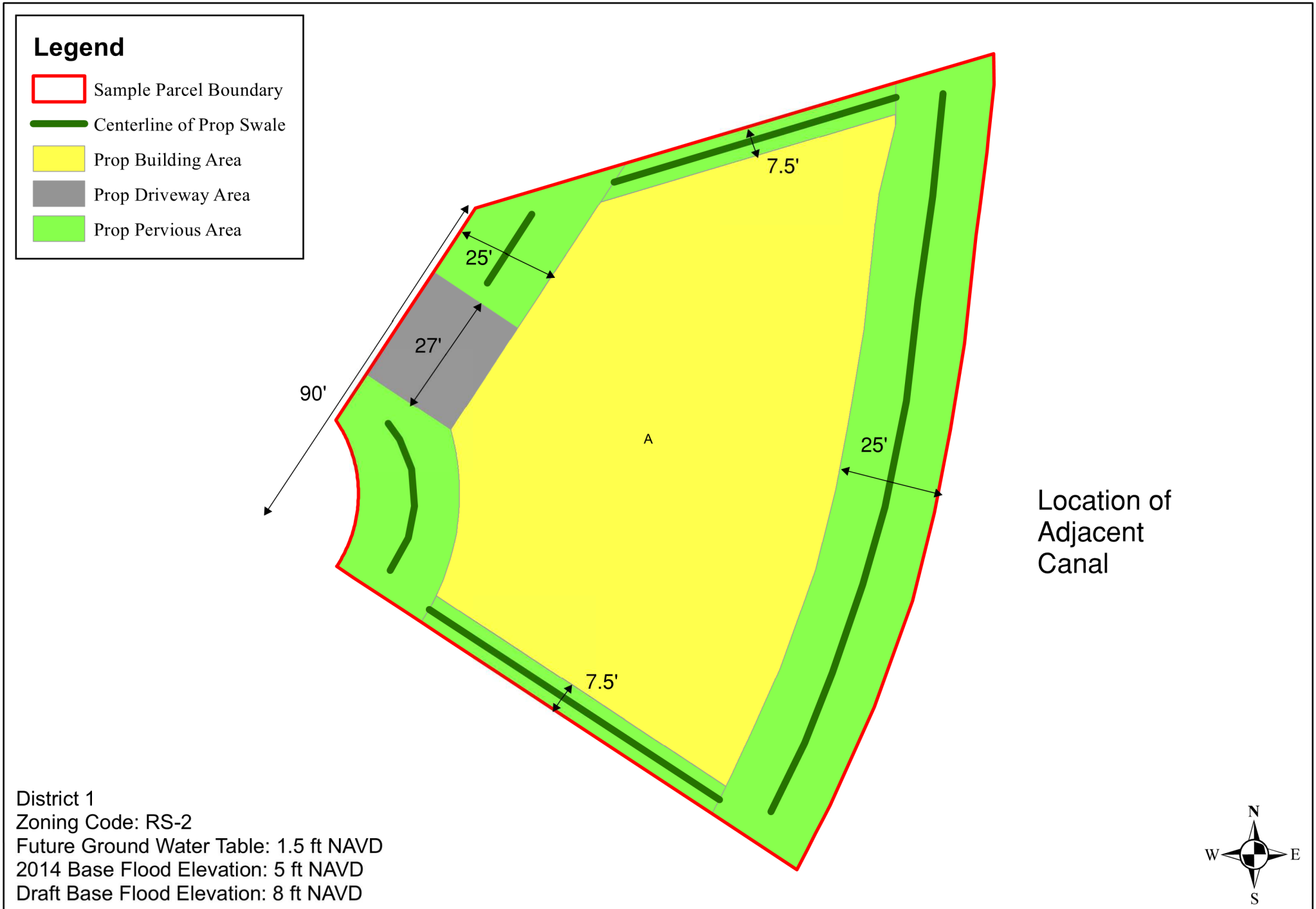
Should you have any questions, please do not hesitate to contact me at my office at (954) 730-0707 – Extension 1003 or on my cell phone at (954) 818-9550 or send me an electronic message at **jmcclair@chenmoore.com**.

Respectfully submitted,



CHEN MOORE AND ASSOCIATES
Jason McClair, PE, CFM, LEED AP
Senior Engineer

Appendix A: Sample Parcel Map Exhibits



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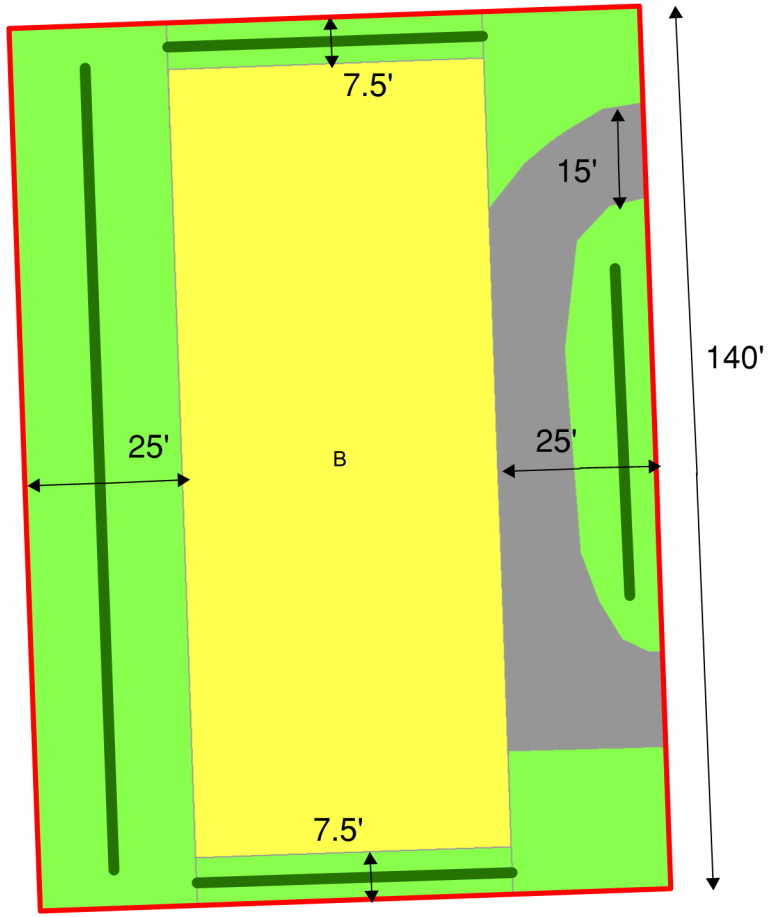
Pompano Beach
Stormwater Regulations Sample Projects
Sample Parcel A

0 30 60 Feet

Legend

- Sample Parcel Boundary
- Centerline of Prop Swale
- Prop Building Area
- Prop Driveway Area
- Prop Pervious Area



Location of Adjacent Canal

District 3
Zoning Code: RS-2
Future Ground Water Table: 1.0 ft NAVD
2014 Base Flood Elevation: 6 ft NAVD
Draft Base Flood Elevation: 7 ft NAVD

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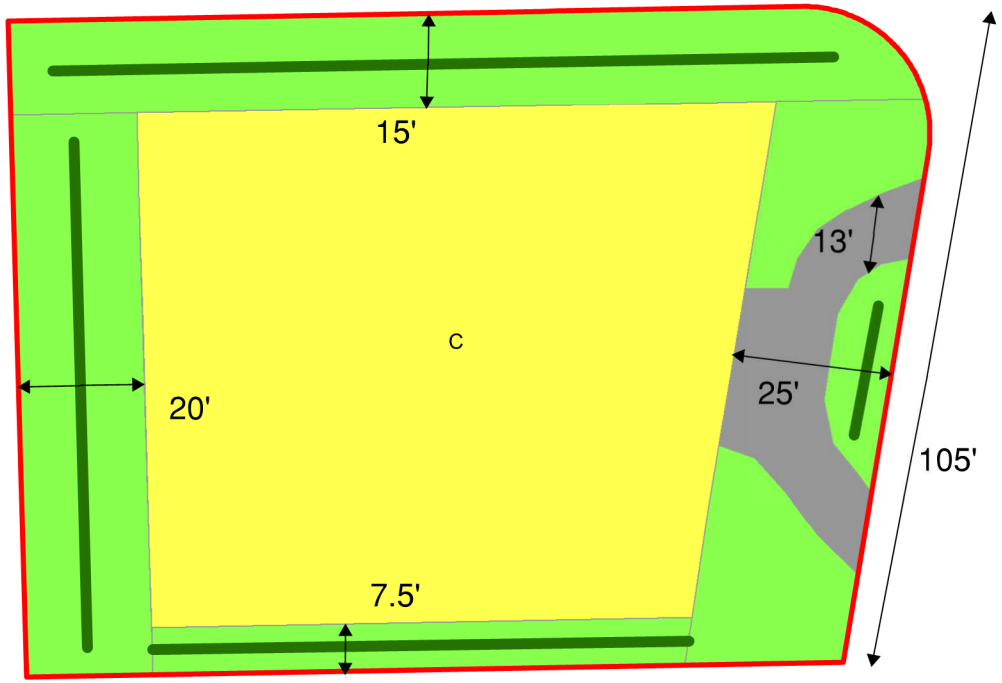
Stormwater Regulations Sample Projects
Sample Parcel B

0 30 60 Feet

Legend

- Sample Parcel Boundary
- Centerline of Prop Swale
- Prop Building Area
- Prop Driveway Area
- Prop Pervious Area



District 1
Zoning Code: RS-2
Future Ground Water Table: 2 ft NAVD
2014 Base Flood Elevation: 5 ft NAVD
Draft Base Flood Elevation: 7 ft NAVD

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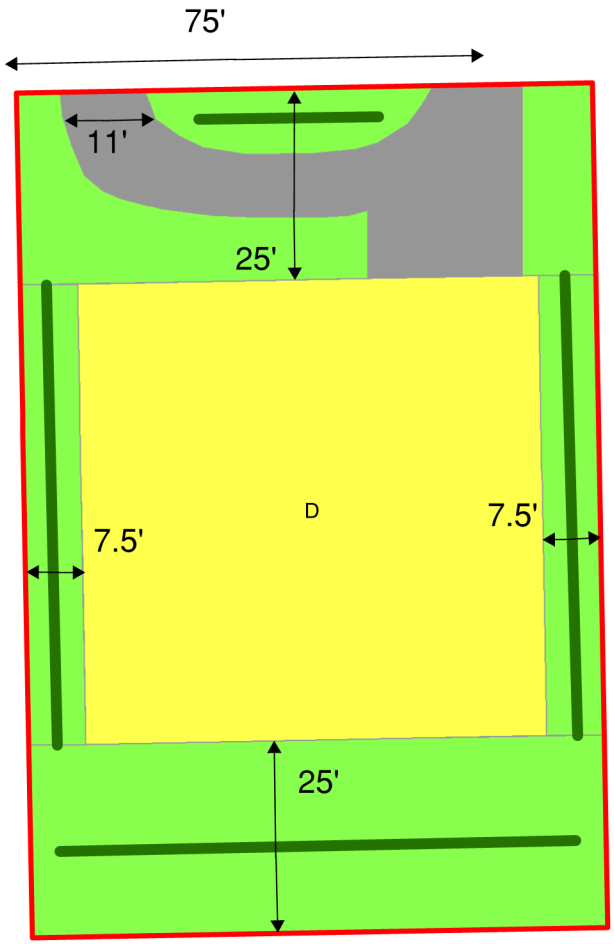
Stormwater Regulations Sample Projects
Sample Parcel C

0 30 60 Feet

Legend

- Sample Parcel Boundary
- Centerline of Prop Swale
- Prop Building Area
- Prop Driveway Area
- Prop Pervious Area



District 1
Zoning Code: RS-2
Future Ground Water Table: 1.5 ft NAVD
2014 Base Flood Elevation: 5 ft NAVD
Draft Base Flood Elevation: 7 ft NAVD

Location of Adjacent Canal

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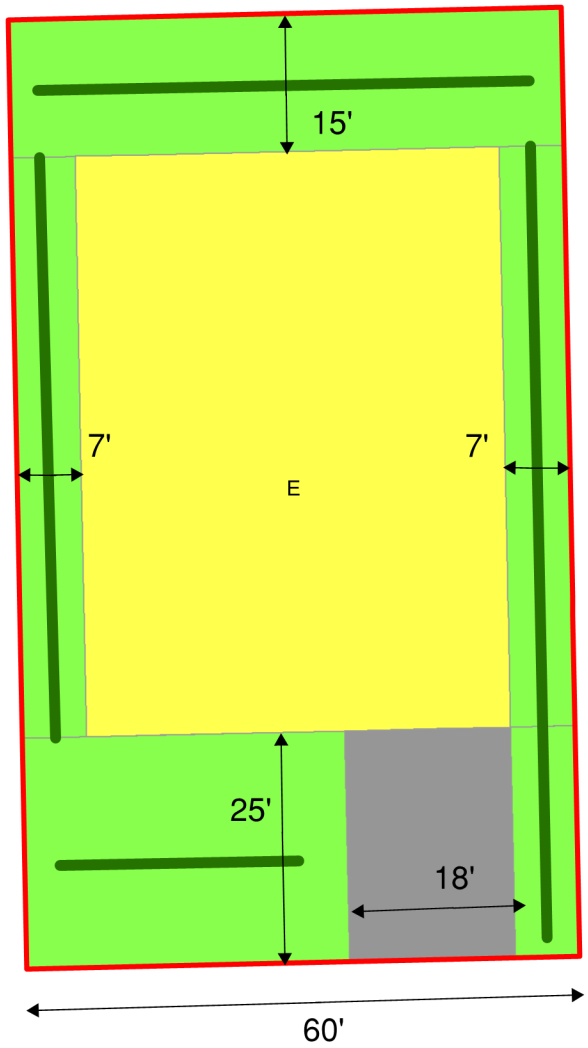
Stormwater Regulations Sample Projects
Sample Parcel D

0 25 50 Feet

Legend

- Sample Parcel Boundary
- Centerline of Prop Swale
- Prop Building Area
- Prop Driveway Area
- Prop Pervious Area



District 5
Zoning Code: RS-3
Future Ground Water Table: 4.5 ft NAVD
2014 Base Flood Elevation: 2% Flood Zone, No BFE
Draft Base Flood Elevation: 2% Flood Zone, No BFE

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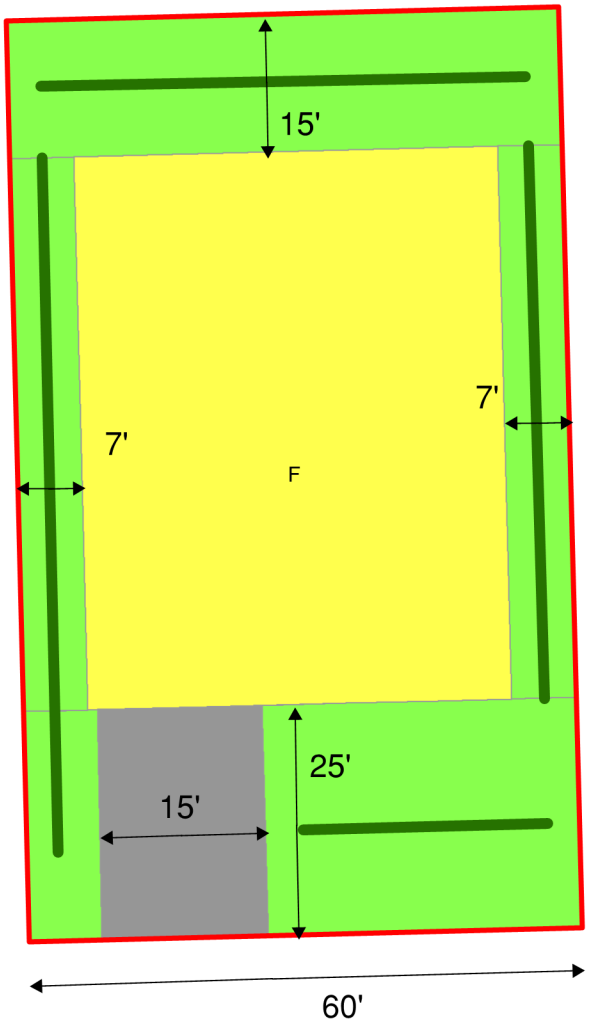
Stormwater Regulations Sample Projects
Sample Parcel E

0 20 40 Feet

Legend

- Sample Parcel Boundary
- Centerline of Prop Swale
- Prop Building Area
- Prop Driveway Area
- Prop Pervious Area



District 4
Zoning Code: RS-3
Future Ground Water Table: 4.5 ft NAVD
2014 Base Flood Elevation: 2% Flood Zone, No BFE
Draft Base Flood Elevation: 2% Flood Zone, No BFE

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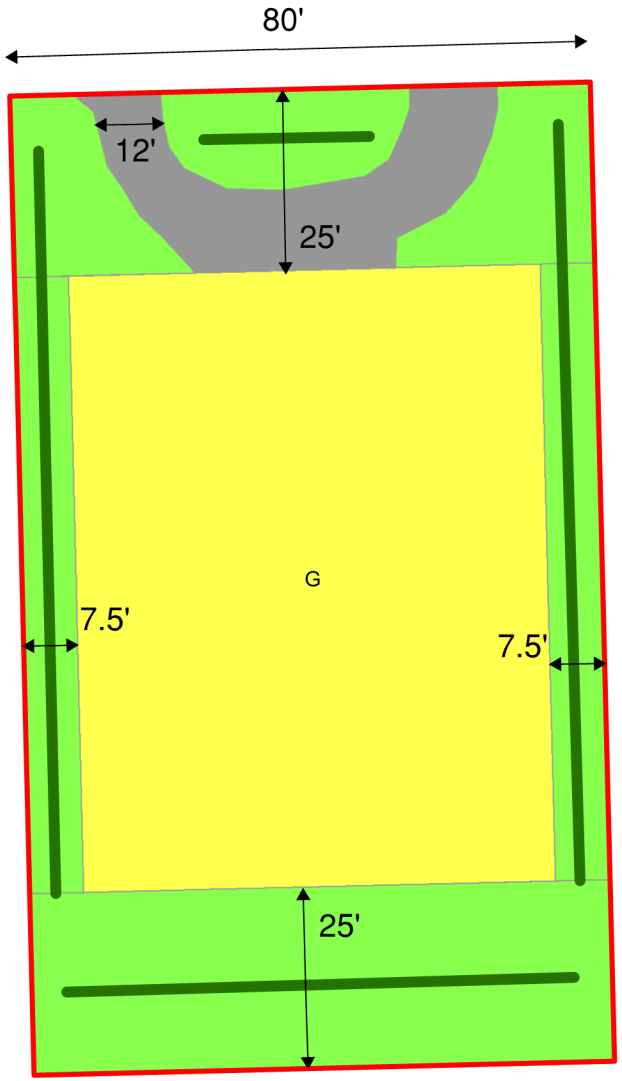
Stormwater Regulations Sample Projects
Sample Parcel F

0 20 40 Feet

Legend

- Sample Parcel Boundary
- Centerline of Prop Swale
- Prop Building Area
- Prop Driveway Area
- Prop Pervious Area



District 1
Zoning Code: RS-2
Future Ground Water Table: 1.5 ft NAVD
2014 Base Flood Elevation: 5 ft NAVD
Draft Base Flood Elevation: 7 ft NAVD

Location of Adjacent Canal

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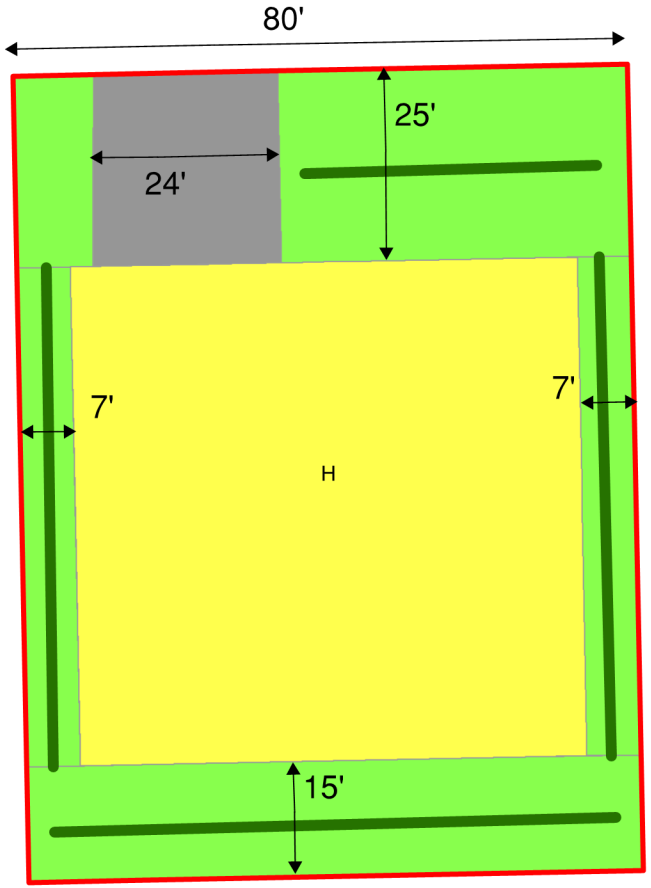
Pompano Beach
Stormwater Regulations Sample Projects
Sample Parcel G

0 25 50 Feet

Legend

- Sample Parcel Boundary
- Centerline of Prop Swale
- Prop Building Area
- Prop Driveway Area
- Prop Pervious Area



District 2
Zoning Code: RS-3
Future Ground Water Table: 3.0 ft NAVD
2014 Base Flood Elevation: 2% Flood Zone, No BFE
Draft Base Flood Elevation: 2% Flood Zone, No BFE

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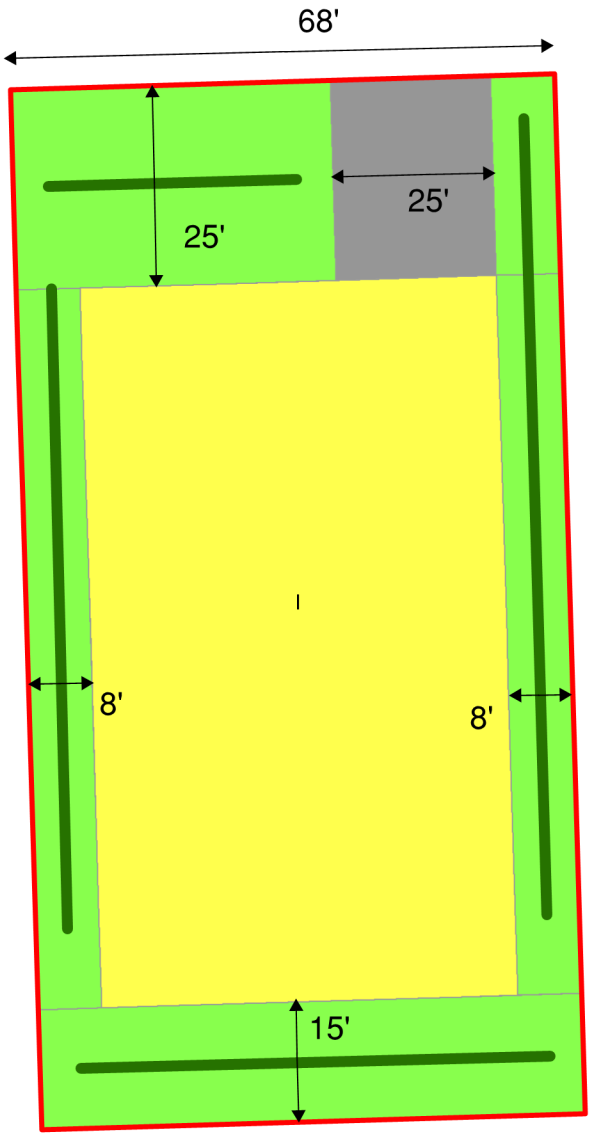
Pompano Beach
Stormwater Regulations Sample Projects
Sample Parcel H

0 25 50 Feet

Legend

- Sample Parcel Boundary
- Centerline of Prop Swale
- Prop Building Area
- Prop Driveway Area
- Prop Pervious Area



District 2
Zoning Code: RD-1
Future Ground Water Table: 3.0 ft NAVD
2014 Base Flood Elevation: 2% Flood Zone, No BFE
Draft Base Flood Elevation: 15 ft NAVD

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Stormwater Regulations Sample Projects
Sample Parcel I

0 25 50 Feet

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Appendix B: Zoning Codes

155.3202. SINGLE-FAMILY RESIDENCE 1 (RS-1)

A. Purpose

The Single-Family Residence 1 (RS-1) District is established and intended to accommodate primarily single-family dwellings at low densities on lots greater than 12,000 square feet in area. The district also accommodates accessory dwelling units as well as limited nonresidential uses usually found in urban single-family neighborhoods, generally as Special Exceptions.

Typical Building Type

B. Use Standards

See Appendix A: Consolidated Use Table, and use-specific standards in Article 4: Use Standards.

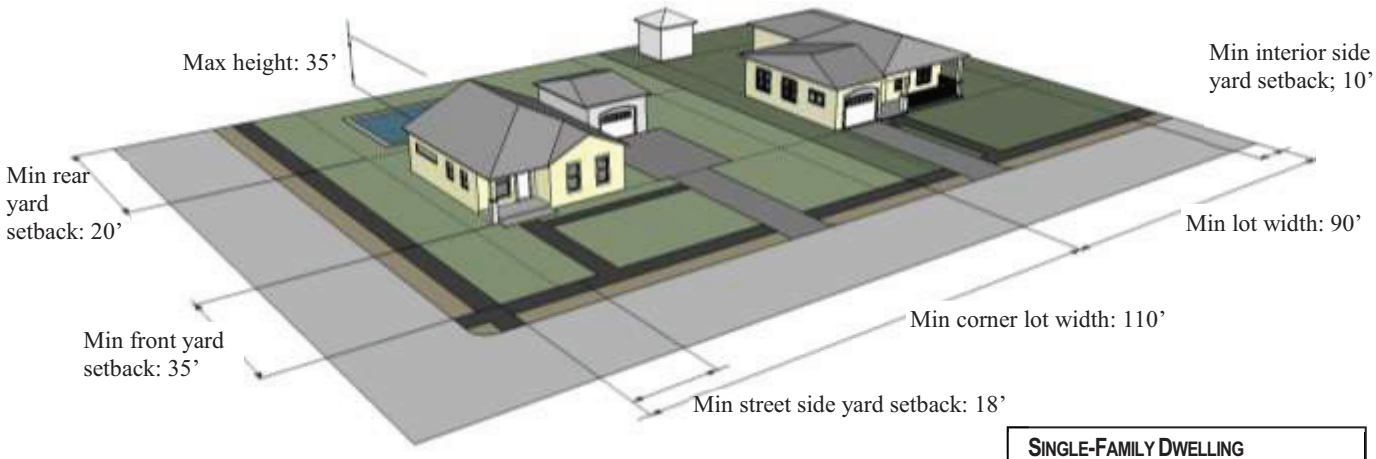
C. Intensity and Dimensional Standards [1]

Lot area, minimum (sq ft)	12,000
Lot width, minimum (ft)	90 [2]
Density, maximum (du/ac)	See Comprehensive Plan [3]
Floor area per dwelling unit, minimum (sq ft)	1,500 for up to 3 bedrooms, plus 100 per additional bedroom
Lot coverage, maximum (% of lot area)	30
Pervious area, minimum (% of lot area)	30
Height, maximum (ft)	35
Front yard setback, minimum (ft)	35
Street side yard setback, minimum (ft)	18
Setback from a waterway or canal, minimum (ft)	25
Interior side yard setback, minimum (ft)	10
Rear yard setback, minimum (ft)	20
Required Front Yard, Pervious Area, minimum (% of Required Front Yard)	50
Dimensional Standards for Accessory Structures	See Accessory Use-Specific standards in Article 4: Part 3.

Typical Lot Pattern

NOTES: [sq ft = square feet; ft = feet; du/ac = dwelling units/acre]
1. See measurement rules and allowed exceptions/variations in Article 9: Part 4 .
2. 110 ft for a corner lot.
3. On land classified Residential by the Land Use Plan, maximum gross residential density may not exceed that established for the particular land use classification.

Typical Development Configuration



Single-Family Dwelling
Min lot area = 12,000 sq ft
Min floor area = 1,500 sq ft
Max lot coverage = 30%

155.3203. SINGLE-FAMILY RESIDENCE 2 (RS-2)

A. Purpose

The Single-Family Residence 2 (RS-2) district is established and intended to accommodate primarily single-family dwellings at moderate densities on lots greater than 7,000 square feet in area. The district also accommodates accessory dwelling units as well as limited nonresidential uses usually found in urban single-family neighborhoods (e.g., parks, places of worship, golf courses), generally as Special Exceptions.

Typical Building Type

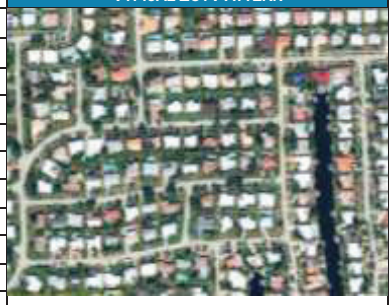
B. Use Standards

See Appendix A: Consolidated Use Table, and use-specific standards in Article 4: Use Standards.

C. Intensity and Dimensional Standards [1]

Lot area, minimum (sq ft)	7,000
Lot width, minimum (ft)	70
Density, maximum (du/ac)	See Comprehensive Plan [2]
Floor area per dwelling unit, minimum (sq ft)	1,250
Lot coverage, maximum (% of lot area)	40
Pervious area, minimum (% of lot area)	30
Height, maximum (ft)	35 [5]
Front yard setback, minimum (ft)	25
Street side yard setback, minimum (ft)	15
Setback from a waterway or canal, minimum (ft)	25 [3]
Interior side yard setback, minimum (ft)	7.5
Rear yard setback, minimum (ft)	20 [5]
Required Front Yard, Pervious Area, minimum (% of Required Front Yard)	50
Dimensional Standards for Accessory Structures	See Accessory Use-Specific standards in Article 4: Part 3.

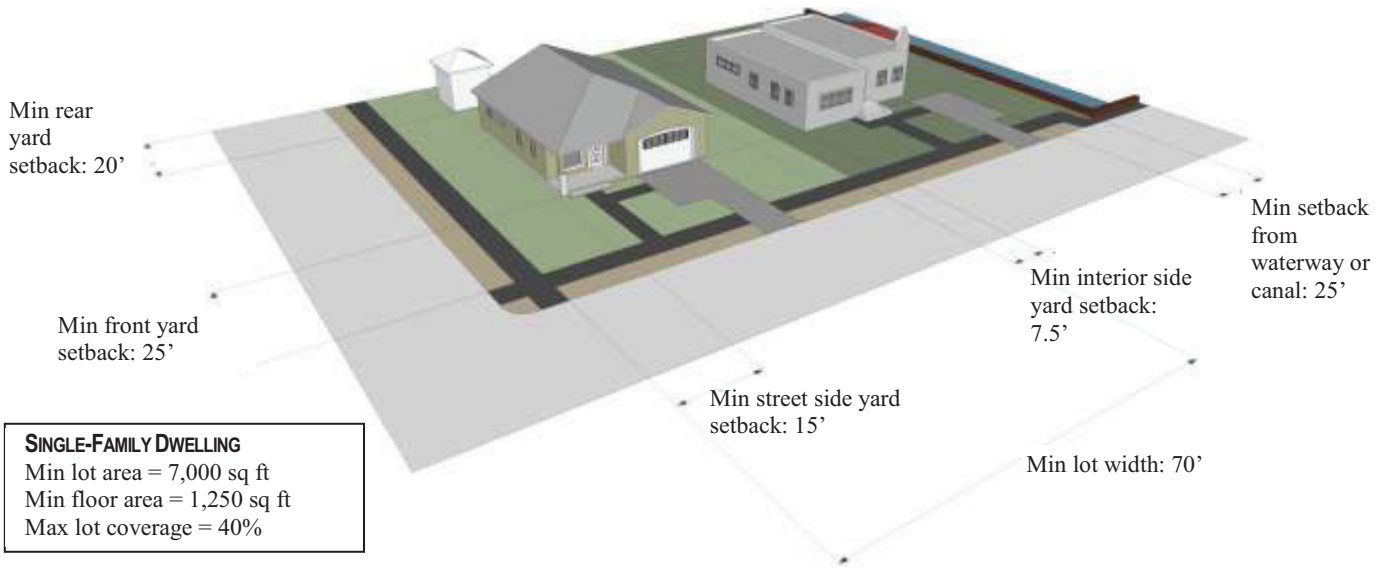
Typical Lot Pattern



NOTES: [sq ft = square feet; ft = feet; du/ac = dwelling units/acre]

1. See measurement rules and allowed exceptions/variations in Article 9:Part 4 .
2. On land classified Residential by the Land Use Plan, maximum gross residential density may not exceed that established for the particular land use classification.
3. On existing lot where rear yard abuts waterway or canal, setback equals the existing rear yard depth if it is between 15 ft and 25 ft.
4. On existing lot, setback equals the existing rear yard depth if it is between 15 ft and 20 ft.
5. The maximum height may be increased to 40 feet where the lowest structural member of a building must be 14.5 feet or more above National Geodetic Vertical Datum of 1929 (N.G.V.D)

Typical Development Configuration



Single-Family Dwelling
Min lot area = 7,000 sq ft
Min floor area = 1,250 sq ft
Max lot coverage = 40%

155.3204. SINGLE-FAMILY RESIDENCE 3 (RS-3)

A. Purpose

The Single-Family Residence 3 (RS-3) district is established and intended to accommodate primarily single-family dwellings at moderate densities on lots greater than 6,000 square feet in area. The district also accommodates accessory dwelling units as well as limited nonresidential uses usually found in urban single-family neighborhoods,, generally as Special Exceptions.

Typical Building Type

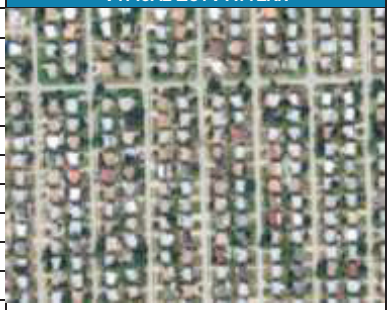
B. Use Standards

See Appendix A: Consolidated Use Table, and use-specific standards in Article 4: Use Standards.

C. Intensity and Dimensional Standards [1]

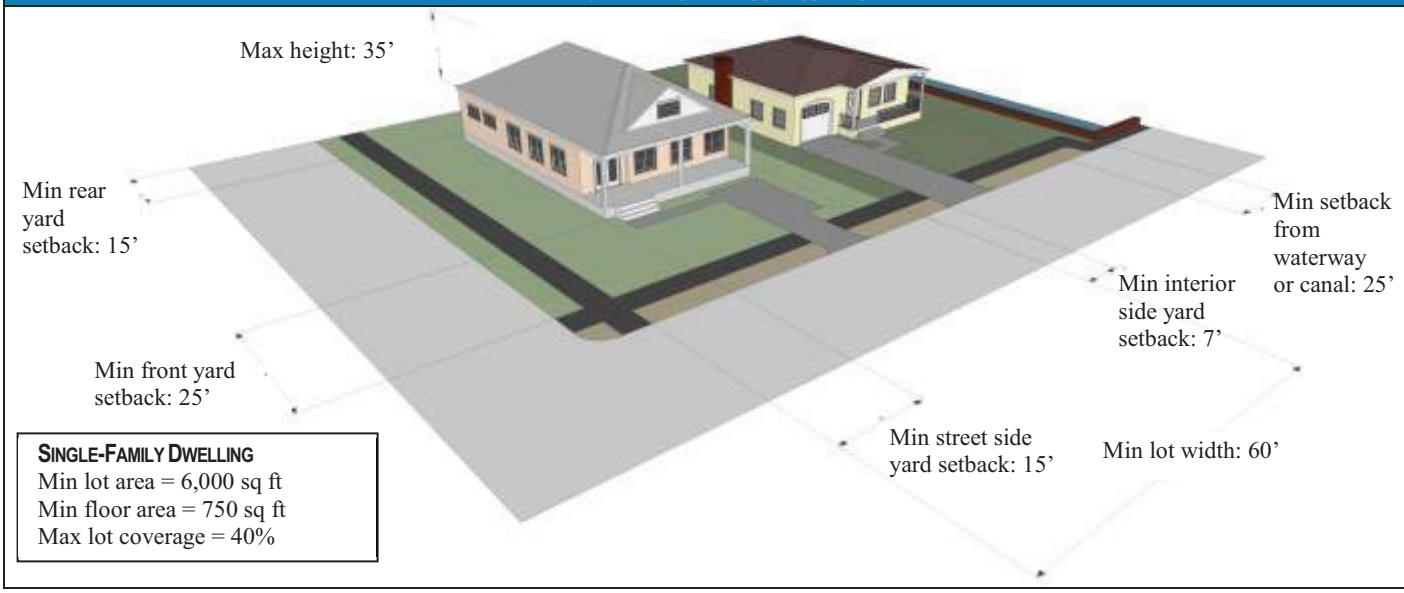
Lot area, minimum (sq ft)	6,000
Lot width, minimum (ft)	60
Density, maximum (du/ac)	See Comprehensive Plan[2]
Floor area per dwelling unit, minimum (sq ft)	750
Lot coverage, maximum (% of lot area)	40
Pervious area, minimum (% of lot area)	30
Height, maximum (ft)	35
Front yard setback, minimum (ft)	25
Street side yard setback, minimum (ft)	15
Setback from a waterway or canal, minimum (ft)	25
Interior side yard setback, minimum (ft)	7
Rear yard setback, minimum (ft)	15
Required Front Yard, Pervious Area, minimum (% of Required Front Yard)	50
Dimensional Standards for Accessory Structures	See Accessory Use-Specific standards in Article 4: Part 3.

Typical Lot Pattern



NOTES: [sq ft = square feet; ft = feet; du/ac = dwelling units/acre]
1. See measurement rules and allowed exceptions/variations in Article 9:Part 4 .
2. On land classified Residential by the Land Use Plan, maximum gross residential density may not exceed that established for the particular land use classification.

Typical Development Configuration



Single-Family Dwelling
Min lot area = 6,000 sq ft
Min floor area = 750 sq ft
Max lot coverage = 40%

155.3207. TWO-FAMILY RESIDENCE (RD-1)

A. Purpose

The Two-Family Residence (RD-1) district is established and intended to accommodate primarily single-family dwellings and two-family dwellings at moderate densities. The district also accommodates accessory dwelling units (with single-family dwellings) as well as limited nonresidential uses usually found in urban single-family neighborhoods (e.g., parks, places of worship, golf courses), generally as Special Exceptions.

Typical Building Type

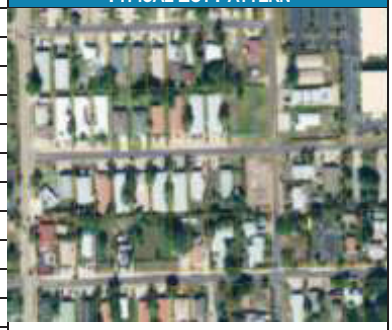
B. Use Standards

See Appendix A: Consolidated Use Table, and use-specific standards in Article 4: Use Standards.

C. Intensity and Dimensional Standards [1]

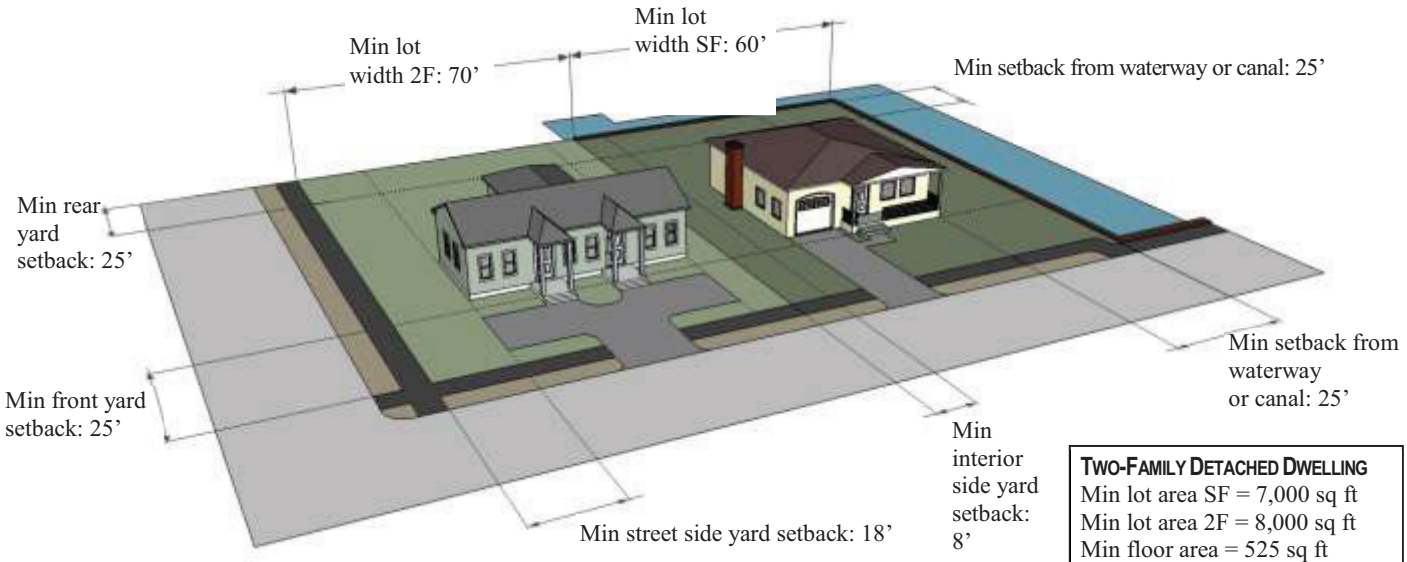
Lot area, minimum (sq ft)	SF: 7,000	2F: 8,000
Lot width, minimum (ft)	SF: 60	2F: 70
Density, maximum (du/ac)	12 [2]	
Floor area per dwelling unit, minimum (sq ft)	750	
Lot coverage, maximum (% of lot area)	35	
Pervious area, minimum (% of lot area)	30	
Height, maximum (ft)	35	
Front yard setback, minimum (ft)	25	
Street side yard setback, minimum (ft)	18	
Setback for a waterway or canal, minimum (ft)	25	
Interior side yard setback, minimum (ft)	8	
Rear yard setback, minimum (ft)	15	
Required Front Yard, Pervious Area, minimum (% of Required Front Yard)	50	
Dimensional Standards for Accessory Structures	See Accessory Use-Specific standards in Article 4: Part 3.	

Typical Lot Pattern



NOTES: [sq ft = square feet; ft = feet; du/ac = dwelling units/acre; SF = single-family dwelling; 2F = two-family dwelling]
1. See measurement rules and allowed exceptions/variations in Article 9:Part 4 .
2. On land classified Residential by the Land Use Plan, maximum gross residential density may not exceed that established for the particular land use classification.

Typical Development Configuration



Two-Family Detached Dwelling
Min lot area SF = 7,000 sq ft
Min lot area 2F = 8,000 sq ft
Min floor area = 525 sq ft
Max lot coverage = 35%

chen moore and associates

Appendix C: Water Quantity Calculations

Water Quantity Calculations for Triangular Swale Storage Areas

Sample Project	Future Ground Water Table Elevation (feet NAVD)	2021 Base Flood Elev. (BFE) (feet NAVD)	Water Quality Storage Requirement (2.8*Area) (ac-in)	Parcel Lot Line Location	Zoning Setback (feet)	Available Width (feet)	Swale Length (feet)	Lowest Perimeter Elevation (feet NAVD)	Ground Water Table plus 1 foot (feet NAVD)	Depth from BFE to Perimeter Elev. (feet)	Depth from Perimeter Elev. to FGWT +1 (feet)	Depth of Swale (feet)	Swale Width available for storage (feet)	Water Quantity Stored in Swale (ac-in)	Water Quantity Available in Sample Parcel (ac-in)	Net Water Quantity in Sample Parcel (ac-in)	Water Quantity in Side Swales Only (ac-in)	Water Quantity in Side Swales Only (ac-in)	Net Water Quantity in Sample Parcel (ac-in)
A	1.50	8.00	1.31	Front	25.00	25.00	59.15	3.30	2.50	4.70	0.80	0.78	6.20	0.04	0.06	-1.25		0.00	-1.31
				North	7.50	7.50	72.49	3.60		4.40	1.10	0.00	-10.10	0.00			0.00		
				Rear	25.00	25.00	183.16	2.70		5.30	0.20	0.20	3.80	0.02					
				South	7.50	7.50	85.41	3.80		4.20	1.30	0.00	-9.30	0.00			0.00		
B	1.00	7.00	0.90	Front	25.00	12.00	51.96	3.80	2.00	3.20	1.80	0.00	-0.80	0.00	0.79	-0.11		0.03	-0.87
				South	7.50	7.50	50.00	6.30		0.70	4.30	0.59	4.70	0.02			0.02		
				Rear	25.00	25.00	127.16	5.40		1.60	3.40	2.33	18.60	0.76					
				North	7.50	7.50	50.00	6.00		1.00	4.00	0.44	3.50	0.01			0.01		
C	2.00	7.00	0.92	Front	8.00	8.00	20.84	2.70	3.00	4.30	-0.30	0.00	-9.20	0.00	0.00	-0.92		0.00	-0.92
				North	15.00	15.00	123.63	2.50		4.50	-0.50	0.00	-3.00	0.00			0.00		
				Rear	20.00	20.00	80.06	2.70		4.30	-0.30	0.00	2.80	0.00					
				South	7.50	7.50	84.99	3.30		3.70	0.30	0.00	-7.30	0.00			0.00		
D	1.50	7.00	0.53	Front	25.00	6.00	23.44	5.00	2.50	2.00	2.50	0.00	-2.00	0.00	0.30	-0.23		0.01	-0.52
				East	7.50	7.50	60.00	5.70		1.30	3.20	0.29	2.30	0.01			0.01		
				Rear	25.00	25.00	67.20	4.70		2.30	2.20	1.98	15.80	0.29					
				West	7.50	7.50	60.00	5.40		1.60	2.90	0.14	1.10	0.00			0.00		
E	4.50	12.00	0.40	Front	25.00	25.00	25.92	11.20	5.50	0.80	5.70	2.73	21.80	0.21	0.28	-0.12		0.02	-0.37
				East	7.00	7.00	85.90	10.80		1.20	5.30	0.28	2.20	0.01			0.01		
				Rear	15.00	15.00	53.40	10.00		2.00	4.50	0.88	7.00	0.05					
				West	7.00	7.00	63.03	11.20		0.80	5.70	0.48	3.80	0.02			0.02		
F	4.50	13.00	0.39	Front	25.00	25.00	26.57	11.10	5.50	1.90	5.60	2.18	17.40	0.14	0.28	-0.11		0.01	-0.37
				East	7.00	7.00	60.00	12.00		1.00	6.50	0.38	3.00	0.01			0.01		
				Rear	15.00	15.00	52.61	12.20		0.80	6.70	1.48	11.80	0.13					
				West	7.00	7.00	75.38	11.60		1.40	6.10	0.18	1.40	0.00			0.00		
G	1.50	7.00	0.69	Front	25.00	14.00	22.79	5.70	2.50	1.30	3.20	1.10	8.80	0.03	0.14	-0.56		0.11	-0.59
				East	7.50	7.50	104.31	6.50		0.50	4.00	0.69	5.50	0.05			0.05		
				Rear	25.00	25.00	69.91	1.70		5.30	-0.80	0.00	3.80	0.00					
				West	7.50	7.50	102.38	6.50		0.50	4.00	0.69	5.50	0.05			0.05		
H	3.00	12.00	0.54	Front	25.00	25.00	38.04	9.30	4.00	2.70	5.30	1.78	14.20	0.13	0.17	-0.37		0.00	-0.54
				East	7.00	7.00	65.00	10.00		2.00	6.00	0.00	-1.00	0.00			0.00		
				Rear	15.00	15.00	73.12	9.70		2.30	5.70	0.73	5.80	0.04					
				West	7.00	7.00	65.00	10.30		1.70	6.30	0.03	0.20	0.00			0.00		
I	3.00	15.00	0.57	Front	25.00	25.00	31.05	13.20	4.00	1.80	9.20	2.23	17.80	0.17	0.29	-0.27		0.04	-0.53
				East	8.00	8.00	99.49	13.70		1.30	9.70	0.35	2.80	0.01			0.01		
				Rear	15.00	15.00	58.61	13.60		1.40	9.60	1.18	9.40	0.09					
				West	8.00	8.00	80.01	14.00		1.00	10.00	0.50	4.00	0.02			0.02		

** Cells Highlighted Red indicate that either the Setback Width is too Narrow for Storage or that the Future Ground Water Table plus 1 foot is above the Perimeter Elevation

Water Quantity Calculations for Trapezoidal Swale Storage Areas

Sample Project	Future Ground Water Table Elevation (feet NAVD)	2021 Base Flood Elev. (BFE) (feet NAVD)	Water Quality Storage Requirement (2.8*Area) (ac-in)	Parcel Lot Line Location	Zoning Setback (feet)	Available Width (feet)	Swale Length (feet)	Lowest Perimeter Elevation (feet NAVD)	Ground Water Table plus 1 foot (feet NAVD)	Depth from BFE to Perimeter Elev. (feet)	Depth from Perimeter Elev. to FGWT +1 (feet)	Depth of Swale (feet)	Swale Width available for storage (feet)	Water Quantity Stored in Swale (ac-in)	Water Quantity Available in Sample Parcel (ac-in)	Net Water Quantity in Sample Parcel (ac-in)	Water Quantity in Side Swales Only (ac-in)	Water Quantity in Side Swales Only (ac-in)	Net Water Quantity in Sample Parcel (ac-in)
A	1.50	8.00	1.31	Front	25.00	25.00	59.15	3.30	2.50	4.70	0.80	0.70	6.20	0.04	0.07	-1.24		0.00	-1.31
				North	7.50	7.50	72.49	3.60		4.40	1.10	0.00	-10.10	0.00			0.00		
				Rear	25.00	25.00	183.16	2.70		5.30	0.20	0.20	3.80	0.03					
				South	7.50	7.50	85.41	3.80		4.20	1.30	0.00	-9.30	0.00			0.00		
B	1.00	7.00	0.90	Front	25.00	12.00	51.96	3.80	2.00	3.20	1.80	0.00	-0.80	0.00	0.54	-0.36		0.03	-0.87
				South	7.50	7.50	50.00	6.30		0.70	4.30	0.55	4.70	0.02			0.02		
				Rear	25.00	25.00	127.16	5.40		1.60	3.40	1.00	18.60	0.51					
				North	7.50	7.50	50.00	6.00		1.00	4.00	0.40	3.50	0.01			0.01		
C	2.00	7.00	0.92	Front	8.00	8.00	20.84	2.70	3.00	4.30	-0.30	0.00	-9.20	0.00	0.00	-0.92		0.00	-0.92
				North	15.00	15.00	123.63	2.50		4.50	-0.50	0.00	-3.00	0.00			0.00		
				Rear	20.00	20.00	80.06	2.70		4.30	-0.30	0.30	2.80	0.00					
				South	7.50	7.50	84.99	3.30		3.70	0.30	0.50	-7.30	0.00			0.00		
D	1.50	7.00	0.53	Front	25.00	6.00	23.44	5.00	2.50	2.00	2.50	0.00	-2.00	0.00	0.23	-0.31		0.01	-0.52
				East	7.50	7.50	60.00	5.70		1.30	3.20	0.25	2.30	0.01			0.01		
				Rear	25.00	25.00	67.20	4.70		2.30	2.20	1.00	15.80	0.22					
				West	7.50	7.50	60.00	5.40		1.60	2.90	0.13	1.10	0.00			0.00		
E	4.50	12.00	0.40	Front	25.00	25.00	25.92	11.20	5.50	0.80	5.70	1.00	21.80	0.13	0.19	-0.21		0.02	-0.38
				East	7.00	7.00	85.90	10.80		1.20	5.30	0.25	2.20	0.01			0.01		
				Rear	15.00	15.00	53.40	10.00		2.00	4.50	0.75	7.00	0.04					
				West	7.00	7.00	63.03	11.20		0.80	5.70	0.25	3.80	0.01			0.01		
F	4.50	13.00	0.39	Front	25.00	25.00	26.57	11.10	5.50	1.90	5.60	1.00	17.40	0.10	0.22	-0.16		0.01	-0.37
				East	7.00	7.00	60.00	12.00		1.00	6.50	0.35	3.00	0.01			0.01		
				Rear	15.00	15.00	52.61	12.20		0.80	6.70	1.00	11.80	0.11					
				West	7.00	7.00	75.38	11.60		1.40	6.10	0.15	1.40	0.00			0.00		
G	1.50	7.00	0.69	Front	25.00	14.00	22.79	5.70	2.50	1.30	3.20	1.00	8.80	0.03	0.14	-0.56		0.11	-0.59
				East	7.50	7.50	104.31	6.50		0.50	4.00	0.65	5.50	0.05			0.05		
				Rear	25.00	25.00	69.91	1.70		5.30	-0.80	0.40	3.80	0.00					
				West	7.50	7.50	102.38	6.50		0.50	4.00	0.65	5.50	0.05			0.05		
H	3.00	12.00	0.54	Front	25.00	25.00	38.04	9.30	4.00	2.70	5.30	1.00	14.20	0.11	0.15	-0.39		0.00	-0.54
				East	7.00	7.00	65.00	10.00		2.00	6.00	0.00	-1.00	0.00			0.00		
				Rear	15.00	15.00	73.12	9.70		2.30	5.70	0.65	5.80	0.04					
				West	7.00	7.00	65.00	10.30		1.70	6.30	0.00	0.20	0.00			0.00		
I	3.00	15.00	0.57	Front	25.00	25.00	31.05	13.20	4.00	1.80	9.20	1.00	17.80	0.12	0.24	-0.33		0.03	-0.54
				East	8.00	8.00	99.49	13.70		1.30	9.70	0.30	2.80	0.01			0.01		
				Rear	15.00	15.00	58.61	13.60		1.40	9.60	1.00	9.40	0.09					
				West	8.00	8.00	80.01	14.00		1.00	10.00	0.30	4.00	0.02			0.02		

** Cells Highlighted Red indicate that either the Setback Width is too Narrow for Storage or that the Future Ground Water Table plus 1 foot is above the Perimeter Elevation

Water Quantity Calculations for Swale Storage Areas with Retaining Walls

Sample Project	Future Ground Water Table Elevation (feet NAVD)	2021 Base Flood Elev. (BFE) (feet NAVD)	Water Quality Storage Requirement (2.8*Area) (ac-in)	Parcel Lot Line Location	Zoning Setback (feet)	Available Width (feet)	Swale Length (feet)	Lowest Perimeter Elevation (feet NAVD)	Ground Water Table plus 1 foot (feet NAVD)	Depth to Bottom of Swale (feet)	Elevation (feet NAVD)	Distance to Bottom of Swale (feet)	Shape of Swale	Water Quantity Stored in Swale (ac-in)	Water Quantity Available in Sample Parcel (ac-in)	Net Water Quantity in Sample Parcel (ac-in)	Water Quantity in Side Swales Only (ac-in)	Water Quantity in Side Swales Only (ac-in)	Net Water Quantity in Sample Parcel (ac-in)
A	1.50	8.00	1.31	Front	25.00	25.00	59.15	3.30	2.50	5.50	2.50	22.00	Trapezoidal	1.12	4.90	3.59		0.31	-1.00
				North	7.50	7.50	72.49	3.60		1.88	6.13	7.50	Triangle	0.14			0.14		
				Rear	25.00	25.00	183.16	2.70		5.50	2.50	22.00	Trapezoidal	3.47					
				South	7.50	7.50	85.41	3.80		1.88	6.13	7.50	Triangle	0.17			0.17		
B	1.00	7.00	0.90	Front	25.00	12.00	51.96	3.80	2.00	3.00	4.00	12.00	Triangle	0.26	2.53	1.64		0.09	-0.81
				South	7.50	7.50	50.00	6.30		0.70	6.30	2.80	Trapezoidal	0.04			0.04		
				Rear	25.00	25.00	127.16	5.40		5.00	2.00	20.00	Trapezoidal	2.19					
				North	7.50	7.50	50.00	6.00		1.00	6.00	4.00	Trapezoidal	0.05			0.05		
C	2.00	7.00	0.92	Front	8.00	8.00	20.84	2.70	3.00	2.00	5.00	8.00	Triangle	0.05	2.05	1.13		1.12	0.20
				North	15.00	15.00	123.63	2.50		3.75	3.25	15.00	Triangle	0.96			0.96		
				Rear	20.00	20.00	80.06	2.70		4.00	3.00	16.00	Trapezoidal	0.88					
				South	7.50	7.50	84.99	3.30		1.88	5.13	7.50	Triangle	0.16			0.16		
D	1.50	7.00	0.53	Front	25.00	6.00	23.44	5.00	2.50	1.50	5.50	6.00	Triangle	0.03	1.25	0.72		0.18	-0.35
				East	7.50	7.50	60.00	5.70		1.30	5.70	5.20	Trapezoidal	0.08			0.08		
				Rear	25.00	25.00	67.20	4.70		4.50	2.50	18.00	Trapezoidal	1.04					
				West	7.50	7.50	60.00	5.40		1.60	5.40	6.40	Trapezoidal	0.10			0.10		
E	4.50	12.00	0.40	Front	25.00	25.00	25.92	11.20	5.50	0.80	11.20	3.20	Trapezoidal	0.07	0.44	0.04		0.15	-0.25
				East	7.00	7.00	85.90	10.80		1.20	10.80	4.80	Trapezoidal	0.10			0.10		
				Rear	15.00	15.00	53.40	10.00		2.00	10.00	8.00	Trapezoidal	0.22					
				West	7.00	7.00	63.03	11.20		0.80	11.20	3.20	Trapezoidal	0.05			0.05		
F	4.50	13.00	0.39	Front	25.00	25.00	26.57	11.10	5.50	1.90	11.10	7.60	Trapezoidal	0.17	0.42	0.03		0.16	-0.23
				East	7.00	7.00	60.00	12.00		1.00	12.00	4.00	Trapezoidal	0.06			0.06		
				Rear	15.00	15.00	52.61	12.20		0.80	12.20	3.20	Trapezoidal	0.09					
				West	7.00	7.00	75.38	11.60		1.40	11.60	5.60	Trapezoidal	0.10			0.10		
G	1.50	7.00	0.69	Front	25.00	14.00	22.79	5.70	2.50	1.30	5.70	5.20	Trapezoidal	0.06	1.25	0.55		0.11	-0.59
				East	7.50	7.50	104.31	6.50		0.50	6.50	2.00	Trapezoidal	0.05			0.05		
				Rear	25.00	25.00	69.91	1.70		4.50	2.50	18.00	Trapezoidal	1.08					
				West	7.50	7.50	102.38	6.50		0.50	6.50	2.00	Trapezoidal	0.05			0.05		
H	3.00	12.00	0.54	Front	25.00	25.00	38.04	9.30	4.00	2.70	9.30	10.80	Trapezoidal	0.35	0.92	0.38		0.22	-0.32
				East	7.00	7.00	65.00	10.00		1.75	10.25	7.00	Trapezoidal	0.11			0.11		
				Rear	15.00	15.00	73.12	9.70		2.30	9.70	9.20	Trapezoidal	0.35					
				West	7.00	7.00	65.00	10.30		1.70	10.30	6.80	Trapezoidal	0.11			0.11		
I	3.00	15.00	0.57	Front	25.00	25.00	31.05	13.20	4.00	1.80	13.20	7.20	Trapezoidal	0.19	0.59	0.02		0.23	-0.34
				East	8.00	8.00	99.49	13.70		1.30	13.70	5.20	Trapezoidal	0.14			0.14		
				Rear	15.00	15.00	58.61	13.60		1.40	13.60	5.60	Trapezoidal	0.17					
				West	8.00	8.00	80.01	14.00		1.00	14.00	4.00	Trapezoidal	0.09			0.09		
Totals															**14.35**	**8.10**		**2.56**	**-3.69**