Etowah Development Runoff Study

ETOWAH
habitat conservation plan

Etowah Development Runoff Study

Prepared for the Etowah HCP Runoff Limits Technical Committee by

R. Alfred Vick, ASLA, LEED AP
Assistant Professor
College of Environment & Design
University of Georgia
Athens, Georgia 30602

Table of Contents

Etowah Development Runoff Study

Introduction

The goal of this study is to test the feasibility of the proposed runoff limits for Priority 1 areas designated in the Etowah HCP. The performance standards for these areas are that "the volume of runoff from storms up to the two-year recurrence interval storm must not exceed that which would occur from the site in an undeveloped, forested condition." (Wenger, Carter and Fowler, 2005)

In order to test the feasibility of this standard, a subdivision plat was provided by a cooperative developer. The proposed subdivision is located within a Priority 1 area in Dawson County. The plan encompasses 94.78 acres, and consists of 188 detached single-family homes, 50 townhomes, and a swimming pool and community building. The single-family lots fall into two general categories: a) 7,500-10,500 s.f. lots with approximately 3,600 s.f. of impervious surface and b) 10,000-15,000 s.f. lots with approximately 4,820 s.f. of impervious surface. The attached plans show the pre-development conditions of the site (Existing Conditions), the proposed subdivision layout (Layout) and the proposed grading plan (Grading) that were provided by the developer.

Evaluation of Pre- and Post-Development Runoff

In order to meet the requirements of the proposed runoff limits for a Priority 1 area, all of the runoff from the site during the 2-year, 24-hour storm that exceeds the pre-development runoff for that same storm event must be *retained* on site. In order to determine the volume of runoff in question, the site's pre- and post-development curve numbers (CN) were determined using the SCS TR-55 method.

The site consists of Fannin, Cartecay, Tallapoosa and Hayseville soil types. 72.4% of the site is considered to be Hydrologic Soil Group (HSG) B, while the remaining 27.6% is considered HSG C. Based on the location of the site, it is assumed that the undisturbed land cover would have been oak-hickory forest. Using this information the pre-development CN for the site was determined.

Cover Description	Land Area (s.f.)	Land Area (% of total)	CN	Weighted CN
Forest, good HSG B	2,989,861 s.f.	72.4%	55	40
Forest, good HSG C	1,138,574 s.f.	27.6%	70	19
				Total Weighted CN = 59

Table 1. Pre-development weighted CN

In order to determine the post-development CN for the site, a detailed analysis of the proposed subdivision was conducted to determine the distribution of impervious area, preserved forest and open space. Impervious areas include: roofs, driveways, sidewalks, and roads. Roof areas were provided by the developer. Forest stands were determined to be any areas that were left undisturbed. Open space (lawns, parkes, cemeteries, golf courses, etc.) were determined to be any areas that were disturbed or graded but did not consist of impervious surfaces. The following chart summarizes these findings.

Cover Description	Land Area (s.f.)	Land Area (% of total)	CN	Weighted CN
Impervious HSG B	930,522	22.5%	98	22.1
Impervious HSG C	305,327	7.4%	98	7.2
Open space, good, HSG B	1,647,307	39.9%	61	24.3
Open space, good, HSG C	460,516	11.2%	74	8.3
Forest, good HSG B	412,032	10.0%	55	5.5
Forest, good HSG C	372,731	9.0%	70	6.3
Total Weighted CN = 74				

Table 2. Post-development weighted CN

The pre and post-development CN's were used to determine the amount of runoff in each condition during the 2-year, 24-hour storm event. The Natural Resource Conservation Service (NRCS) provides storm data for various locations throughout the country, and for Dawson County, GA that 2-year storm is determined to be 3.9 inches of rainfall.

Return period	2	5	10	25	50	100	1
Q_{depth}	3.9	5.0	5.9	6.9	7.8	8.0	3.0

Table 3. Storm data for Dawson County, GA (provided by the NRCS)

Using the SCS method, the pre and post-development runoff amounts for the 2-year recurrence storm (3.9 in) were calculated to be:

Pre-development runoff = .67 inches
Post-development runoff = 1.52 inches

These depths were converted to a volume by multiplying by the area of the site.

Pre-development runoff = 230,504 c.f.
Post-development runoff = 522,935 c.f.

By looking at the difference between these two numbers we can conclude that the development of this site as shown on the plan will increase the volume of runoff from the 2-year, 24-hour storm by 292,431 c.f.

The performance standards state that this increase in volume must be infiltrated on-site. Conventional stormwater detention is not acceptable for managing this volume as it does not retain water on-site, it only delays its departure from the site. On-site infiltration must be carefully planned so that the soil is capable of infiltrating the required volumes within an acceptable timeframe. Much research has shown that conventional stormwater detention design that conveys significant portions of the site's runoff to one location is not acceptable for infiltration. A small percentage of the site's area simply cannot infiltrate all of the increased runoff from a much larger area. The most straightforward solution to this problem is to distribute many small infiltration facilities throughout the site, each one dealing with a small percentage of the site's increased runoff.

This concept can be taken one step further by designing a "treatment train". A treatment train is a series of stormwater practices that together perform better than using one practice exclusively. For example, one could design a system in which the pollutant-laden "first flush" of runoff from impervious streets is conveyed to a bioretention area where many pollutants are filtered out, and runoff in excess of the first flush is conveyed to an infiltration area.

One significant benefit is that the volume of water conveyed to the bioretention area and the volume conveyed to the infiltration area can be calculated to match the volumes of rainfall that were intercepted and infiltrated before runoff began and after runoff began (respectively) during pre-development conditions (Echols, 2002). This, in effect, will restore the natural hydrologic processes of the site to pre-development conditions.

The pre-development 2-year, 24-hour rainfall (3.9 in) can be divided into three separate numbers. The *Initial Abstraction* (I_a) is "all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation and infiltration." (USDA, 1986) *Runoff* is the second component, and it has already been calculated. The third component is the rainfall that is retained on-site through *infiltration and evapo-transpiration* after runoff begins. These three processes account for all rainfall that falls on the site, and they can be calculated for the pre-development conditions using the SCS TR-55 method. (See the Appendix for further detail on how this was calculated.) The stormwater redesign presented in the next section will attempt to re-establish the pre-development distribution of rainfall among these three processes.

	Depth (in)	Volume (c.f.)	% of total rainfall
Initial Abstraction (I_a)	1.39	478,211	35.6
Runoff (Q)	.67	230,504	17.2
Retention after runoff begins (S_{actual})	1.84	633,027	47.2
Rainfall (P)	3.9	1,341,742	100

Table 4. Distribution of pre-development 2-year, 24-hour rainfall (3.9 in) among three hydrologic processes

For the sake of comparison, the post-development runoff without bioretention and infiltration would have the following proportions.

	Depth (in)	Volume (c.f.)	% of total rainfall
Initial Abstraction (I_a)	.70	240,825	17.9
Runoff (Q)	1.52	522,935	39.0
Retention after runoff begins (S_{actual})	1.68	577,982	43.1
Rainfall (P)	3.9	1,341,742	100

Table 5. Distribution of post-development 2-year, 24-hour rainfall (3.9 in) among three hydrologic processes

To summarize the above tables, during the 2-year, 24-hour rainfall event, conventional development on this site would:

a. increase runoff by 127%.

b. decrease total storage and infiltration by 26%.

c. Decrease the size of rainfall event that causes runoff by half (from 1.39 in to .70 in).

Redesign to meet the Runoff Limits Plan

The conditions above are not acceptable in a Priority 1 area. In order to mitigate the impacts of developing the site, and to bring it back within the regulations of the proposed Runoff Limits Program a conceptual stormwater plan (see attached plan – Bioretention) has been developed which will provide:

a. 237,386 c.f. of bioretention volume. This amount is equal to the difference between pre- and post-development I_a.

b. 55,045 c.f. of infiltration volume. This amount is equal to the difference between pre- and post-development S_{actual}.

The benefits of using two BMPs to infiltrate the required volume of increased runoff are twofold. First, the bioretention areas act as a filter to treat runoff before it enters the infiltration areas removing fine particles of silt and clay that, if introduced into the infiltration areas could reduce their performance over time. It is presumed that the bioretention areas will be easier to access and maintain, so this is a desirable arrangement to ensure proper functioning of the stormwater system.

An extremely important consideration is the order that runoff moves through this “treatment train”. When runoff from impervious surfaces begins, it should first flow into the bioretention areas. Once the bioretention areas are full, they should overflow and a portion of continued runoff should be directed to the infiltration areas and a portion should continue as runoff. This can be done through the use of a “flow-splitter” in the bioretention overflow structure as described by Echols (2002).

The bioretention and infiltration areas are small and distributed throughout the site so that they are not overloaded. In the single-family residential zone, each lot has a bioretention and infiltration area and in the multi-family zone each driveway has its own bioretention area while the rooftops are directed to shared bioretention areas and infiltration areas.

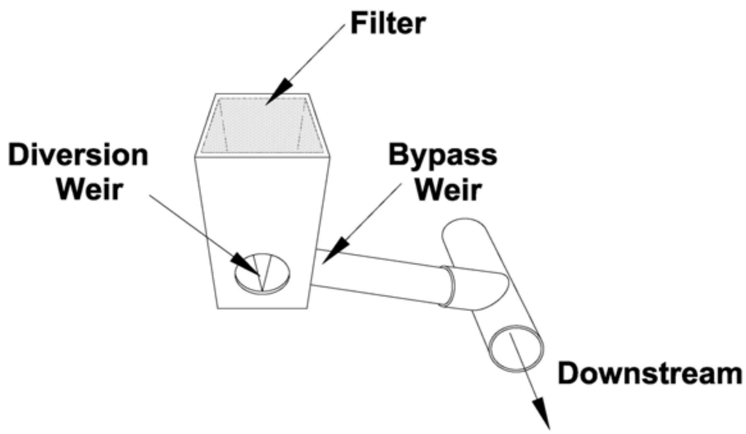


Figure 1. Simple flow-splitter device (image provided by Stuart Patton Echols)

The BMPs for each lot are sized to handle the additional runoff created by that lot and taking into account the Hydrologic Soil Group of that actual lot. The bioretention areas for each lot range in size from 375-625 s.f. with a depth of approximately one foot. The infiltration areas for each lot range from 500-850 c.f. These bioretention areas are typically located in the front yard of the lot, if possible, and aesthetically could have the appearance of a landscape island. The infiltration areas are typically located under the driveways, utilizing one of several available products suitable for infiltration under vehicular traffic.

Figure 2. Typical bioretention area appearance (Photo by R.A. Vick)

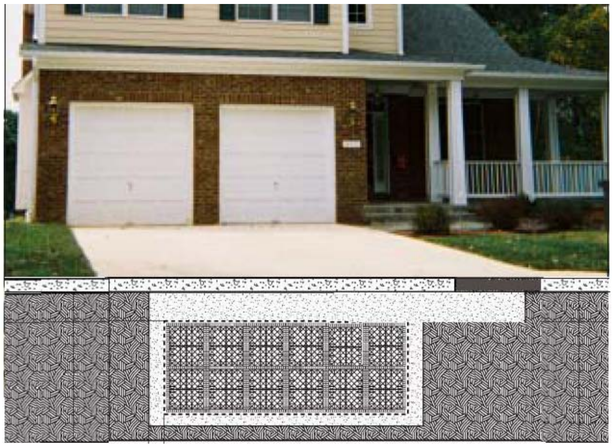


Figure 3. Infiltration chamber located below driveway (image provided by Atlantis Water Management Systems)

The bioretention areas along the roadways are sized to handle the adjacent length of roadway. In this way, most impervious surfaces flow directly into bioretention areas rather than first being concentrated in pipes, which would add cost and velocity. The infiltration areas for the roadways are located under the roadways or sidewalks themselves. Several examples of projects similar to this exist in the Seattle area.

Figure 4. Bioretention areas along a street in Seattle (image provided by Greenworks)

An alternative configuration was looked at that grouped the bioretention and infiltration areas into clusters, each dealing with the runoff from no more than one acre of impervious surface and located on public property in order to facilitate maintenance. This configuration would require the loss of approximately 17 of the single family lots and no loss of the townhome units.

Summary

This study has shown that by carefully distributing numerous bioretention and infiltration areas throughout this site, it was possible to meet the requirements of the proposed Runoff Limits Program without significantly altering the layout that was provided by the developer of the property. The only minor changes that were made were: the slight increase in the width of the planting strip between curb and sidewalk (although no change was made to the width of the right-of-way) and the use of a significant amount of land (on private property, public and community property) for landscaped bioretention areas.

By making these changes, the development would retain 292,431 c.f. of stormwater runoff on the property, allowing it to infiltrate into the soil and protecting sensitive fish species from altered flows and degraded habitat downstream from the project site.

References

Echols, Stuart P., 2002, *Split-Flow Method: Introduction of a New Stormwater Management Strategy*, Stormwater, July, 2002 (www.forester.net)

USDA, 1986, *Urban Hydrology for Small Watersheds: TR-55*.

Wenger, Carter and Fowler, 2005, *Overview of the Runoff Limits Program*, Etowah HCP Runoff Limits Technical Committee.

Appendix A: Calculations

Method

1. Determine the pre- and post-development curve numbers for the site.

    a. Determine the site's Hydrologic Soil Groups (HSG).
    % Type B = 72.4% (2,989,861 s.f.)
    % Type C = 27.6% (1,138,574 s.f.)

    b. Determine the pre-development land cover.
    Based on the location of the site, it can be assumed that the undisturbed land cover would have been oak-hickory forest. Therefore, an SCS Cover Description of "Woods, good stand" will be used.

    c. Determine the pre-development weighted curve number (CN).

Cover Description	Land Area (s.f.)	Land Area (% of total)	CN	Weighted CN
Forest, good HSG B	2,989,861 s.f.	72.4%	55	40
Forest, good HSG C	1,138,574 s.f.	27.6%	70	19
Total Weighted CN = 59				

    d. Determine the post-development weighted CN.
    Impervious areas include: roofs, driveways, sidewalks, and roads. Roof areas were provided by the developer.
    Forest stands were determined to be any areas that were left undisturbed.
    Open space (lawns, parkes, cemeteries, golf courses, etc.) were determined to be any areas that were disturbed or graded but did not consist of impervous surfaces.

Cover Description	Land Area (s.f.)	Land Area (% of total)	CN	Weighted CN
Impervious HSG B	930,522	22.5%	98	22.1
Impervious HSG C	305,327	7.4%	98	7.2
Open space, good, HSG B	1,647,307	39.9%	61	24.3
Open space, good, HSG C	460,516	11.2%	74	8.3
Forest, good HSG B	412,032	10.0%	55	5.5
Forest, good HSG C	372,731	9.0%	70	6.3
Total Weighted CN = 74				

2. Determine pre and post-development runoff for the site (Dawson County, GA).

   a. Determine storm data (provided by the NRCS)

Return period	2	5	10	25	50	100	1
Q_{depth}	3.9	5.0	5.9	6.9	7.8	8.0	3.0

   b. Using Equation 2-3 from SCS TR-55, calculate the runoff depths.

   $Q = (P – 0.2S)^2 /(P + 0.8S)$ [eq. 2-3]

   Where,

   Q = runoff (in)
   P = rainfall (in)
   S = potential maximum retention after runoff begins (in)
   I_a = initial abstraction (in)

   S can be calculated using equation 2-4,

   $S = (1000/CN) – 10$ [eq. 2-4]

   For the 2-year recurrence storm (3.9 in), the following runoff depths are calculated:

   Pre-development runoff = .67 inches
   Post-development runoff = 1.52 inches

   c. Convert to a volume by dividing by 12 and multiplying by the area of the site.

   Pre-development runoff = .67 inches/12 x 4,128,437.46 s.f.
   = 230,504 c.f.
   Post-development runoff = 1.52 inches/12 x 4,128,437.46 s.f.

= 522,935 c.f.

d. Subtract pre- from post-development runoff to get the increase in runoff due to development.

   The development of this site as shown on the plan will increase the volume of runoff from the 2-year, 24-hour storm by 292,431 c.f.

3. We can divide the pre-development 2-year, 24-hour rainfall (3.9 in) into three separate numbers:
   a. the Initial Abstraction (I_a) is "all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation and infiltration." (USDA, 1986)

      This number is calculated using equation 2-2 from SCS TR-55:

      $I_a = 0.2S$, [eq. 2-2]

      where S is calculated using equation 2-4 above.

   b. Runoff is the second component, and it has already been calculated.

   c. The third component is the rainfall that is retained on-site through infiltration and evapo-transpiration after runoff begins. We will call this S_{actual}. The S represented in equations 2-2 and 2-4 is the "*potential maximum* retention after runoff begins", so S_{actual} must be less than S. S_{actual} can be calculated as:

      $S_{actual} = P – I_a – Q$

4. For the study site, the pre-development 2-year, 24-hour rainfall (3.9 in) can be divided as follows:

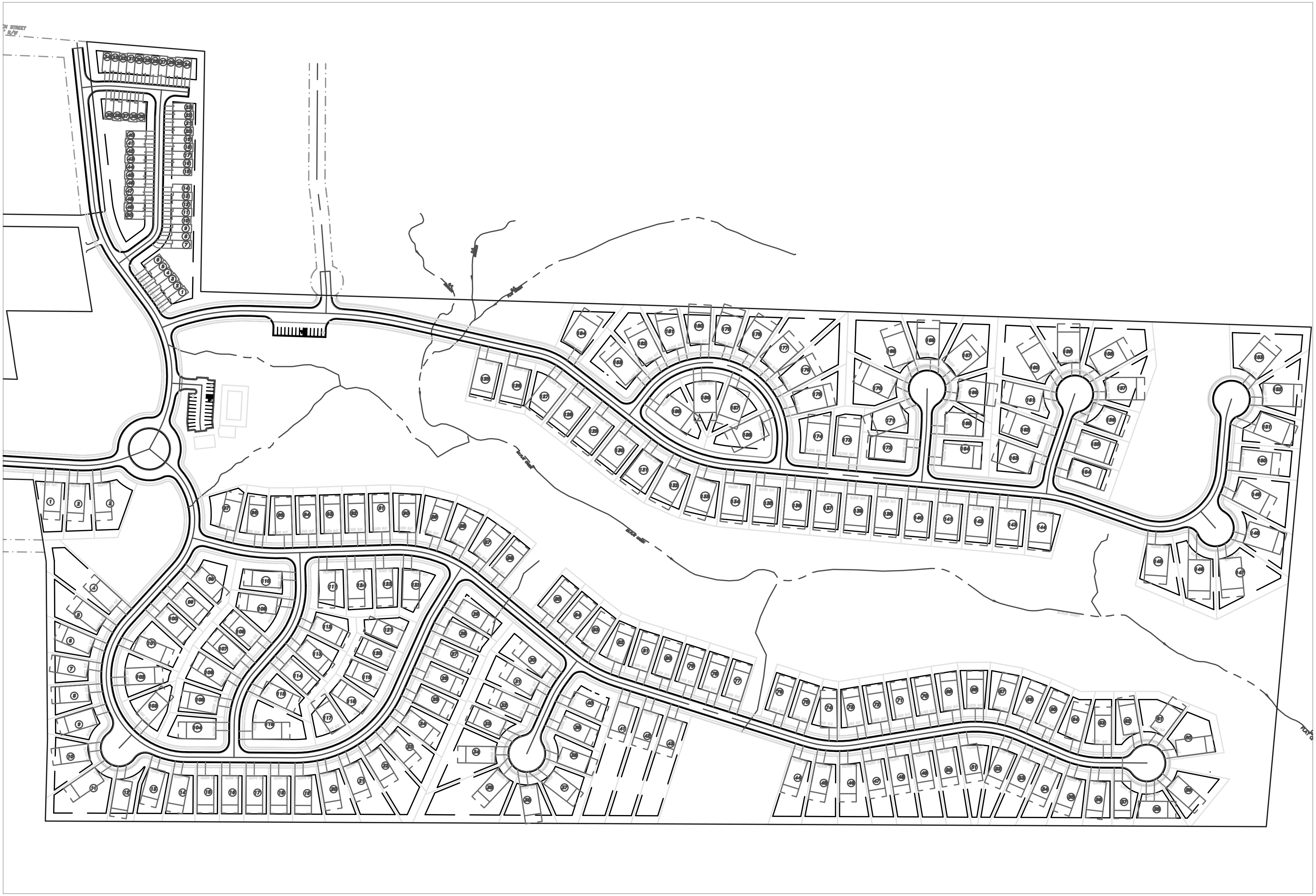
	Depth (in)	Volume (c.f.)	% of total rainfall
Initial Abstraction (I_a)	1.39	478,211	35.6
Runoff (Q)	.67	230,504	17.2
Retention after runoff begins (S_{actual})	1.84	633,027	47.2
Rainfall (P)	3.9	1,341,742	100

These numbers are useful because we can target these same proportions for the post-development conditions by providing bioretention areas to accommodate the I_a volume, and infiltration areas to accommodate the S_{actual} volume. If that is accomplished successfully, the remaining post-development runoff volume will be the same as the pre-development conditions.

5. For the sake of comparison, the post-development runoff without bioretention and infiltration would have the following proportions:

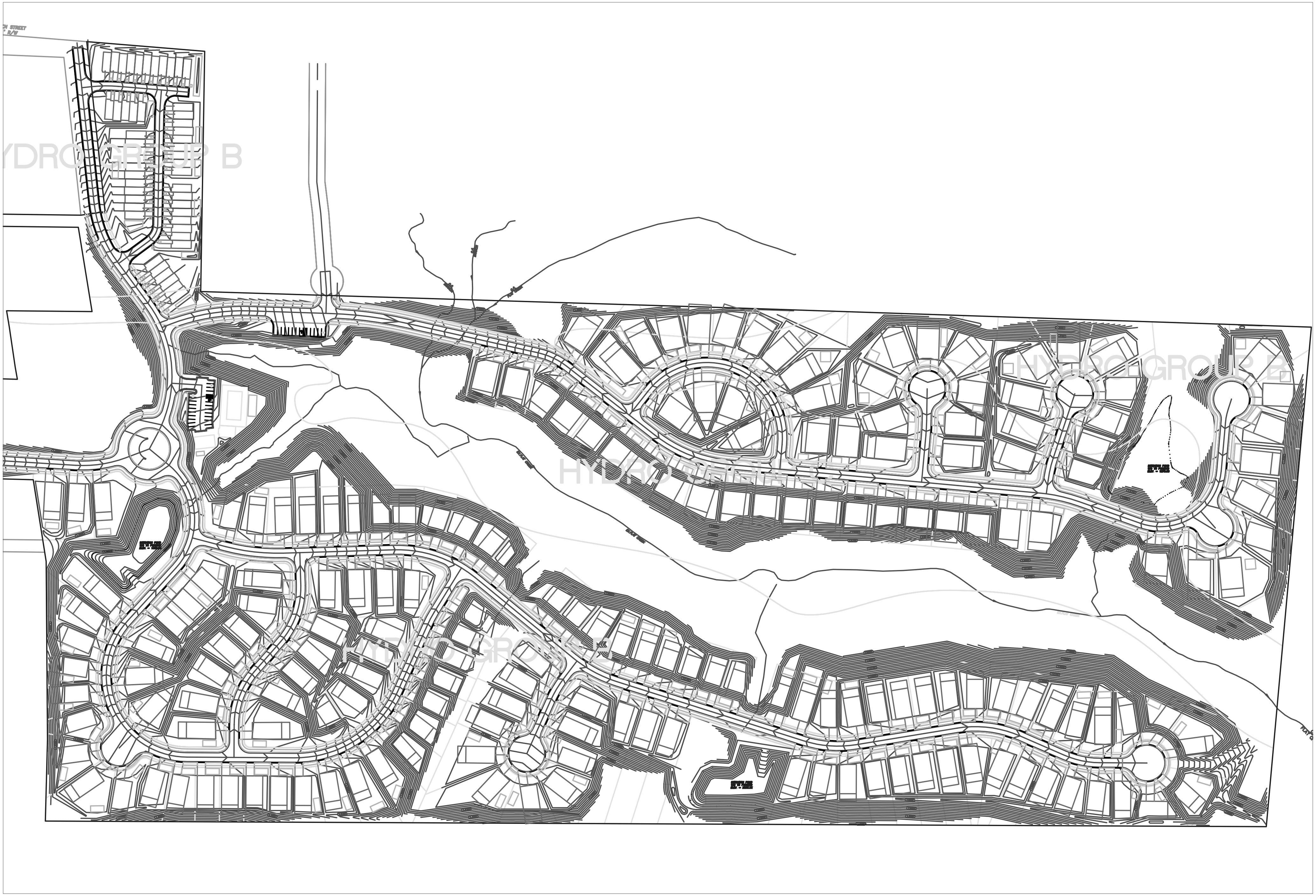
	Depth (in)	Volume (c.f.)	% of total rainfall
Initial Abstraction (I_a)	.70	240,825	17.9
Runoff (Q)	1.52	522,935	39.0
Retention after runoff begins (S_{actual})	1.68	577,982	43.1
Rainfall (P)	3.9	1,341,742	100

Appendix B: Plans



LAYOUT

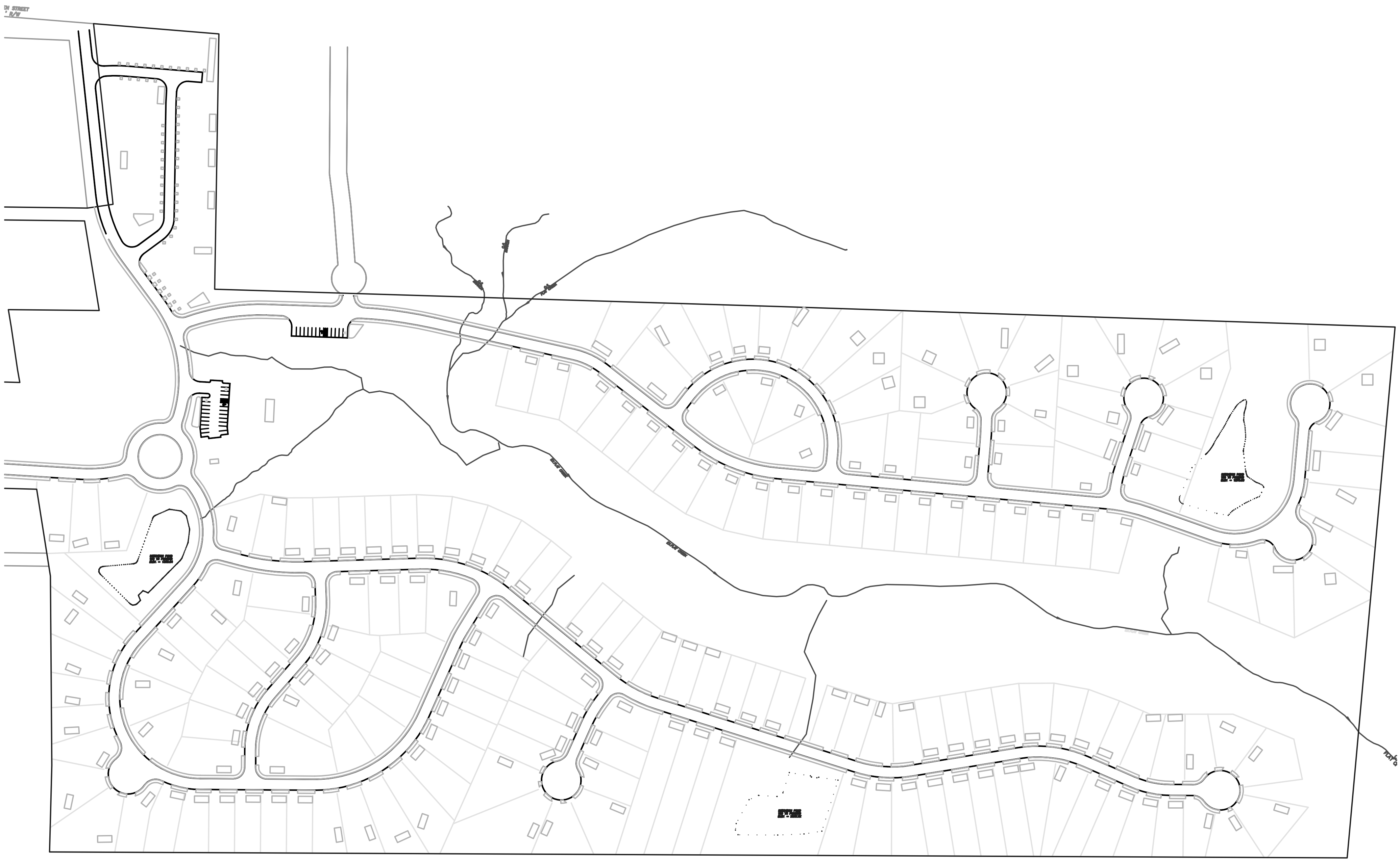
SCALE: 1"=300'
NORTH



GRADING

SCALE: 1"=300'

NORTH



BIORETENTION

SCALE: 1"=300'

NORTH