Clean Water Services

North Bethany Stormwater Implementation Plan

October 9, 2013

Brown AND Caldwell

FINAL

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Prepared for

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REGISTERED PROFESSIONAL ENGINEER
13,681
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JULY 16, 1987
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10/09/2013

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Executive Summary

Introduction

The North Bethany plan area is approximately 674 acres of unincorporated Washington County, located east of Northwest 185th Avenue and between Northwest Germantown Road and Northwest Springville Road. The North Bethany plan area was included in METRO's Urban Growth Boundary (UGB) expansion in 2002. Clean Water Services (District) has conducted ongoing comprehensive planning efforts for this area since its inclusion in the UGB due to its size, location, and jurisdictional coverage. This North Bethany Stormwater Implementation Plan (Plan) builds on the information provided by the *North Bethany Subarea Drainage Master Plan* (DMP) adopted in December 2010 (per Washington County Ordinance 730) and the revised land use designations and development criteria adopted in October 2011 (per Washington County Ordinance 739-A). The Plan describes minimum stormwater management requirements for addressing the water quality and quantity needs of the plan area.

Purpose

The purpose of this Plan is to provide a summary of the hydrologic/hydraulic modeling methods used to size regional stormwater management facilities (RSFs) and to present the findings, including minimum facility sizes and estimated construction costs as required for the plan area. This Plan is intended to be used as guidance for developers, engineers, and District and County staff in developing the stormwater infrastructure in the North Bethany plan area.

The RSFs defined in this Plan are preliminarily sized to provide guidance to all persons interested in the development of this area. The District emphasizes that the sizing of the RSFs is preliminary and that changing development patterns and configurations, and later land uses or densities may modify the required sizing. Detailed design of RSFs and infrastructure should be conducted once survey work has been completed and in consideration of the site application of other stormwater management facilities (i.e., low-impact development approaches or LIDA). The District is open to RSF design alternatives that provide the same water quality treatment and water quantity control as shown in this Plan.

Strategy

RSFs were located at the downstream portion of each subbasin to allow for gravity flow to the facility. To the extent possible, RSFs were located adjacent to natural resource areas (i.e., vegetated corridors) to provide additional habitat value and integration with the natural landscape.

A conventional (rounded) extended dry basin was used as the preliminary RSF configuration for each subbasin. Sizing of each RSF was driven by the available area within the subbasin, the grade and slope of the available area, and the projected development patterns within the subbasin. The preliminary sizing of the RSFs represents a refinement over the original concepts provided in the DMP. More specific design parameters and design assumptions have been incorporated into the sizes. Also, the preliminary RSFs reflect detailed hydrologic/hydraulic modeling of the facilities and grading, and the incorporation of revised parcel boundaries, streets, and development patterns proposed in Washington County's Ordinance 739.

Although LIDA is applied primarily for water quality treatment, select LIDA facilities can provide some water quantity control benefits through infiltration and management of stormwater runoff volumes. This runoff volume reduction is reflected in the sizing of the RSFs. Because of the difficulty in predicting development patterns and configurations, preliminary sizing of the RSFs does not reflect the application of LIDA in areas that are not required to implement site LIDA. However, if infiltration-based LIDA is applied in these areas, the surface area of the RSF facility could be reduced. This Plan includes guidelines to estimate the potential RSF size reduction.

RSF Sizing and Costs

Figure ES-1 shows the proposed general locations of the RSFs. Table ES-1 summarizes the preliminary RSF sizes, including general subbasin characteristics, and the estimated construction costs. These estimates do not include costs associated with land acquisition, including easements, appraisals, and administration. Financing methods and funding sources are not a part of this Plan.

Table ES-1. Regional Stormwater Facility Sizing and Cost Summary

Subbasin	Contributing drainage areas			Peak storage[a] (25-year event)		Top of facility[d] (including freeboard)		Estimated cost[g,h] 2012 ($)
	Total contributing (ac)	Pre-developed impervious area (ac)	Post-developed impervious area (ac)	Surface area[b] (ac)	Volume[c] (ac-ft)	Surface area[e] (ac)	Volume[f] (ac-ft)	
01	28.8	1.3	16.1	0.56	1.49	0.60	2.08	462,700
02	43.9	1.3	23.2	1.09	3.00	1.15	4.14	914,400
03	28.1	1.7	15.4	0.68	1.84	0.73	2.56	633,700
04	30.3	2.3	17.2	0.70	1.89	0.75	2.62	579,900
05	32.2	1.4	18.5	0.63	1.70	0.68	2.36	513,600
06	29.9	1.3	14.6	0.52	1.38	0.56	1.93	512,400
07	41.0	0.3	21.5	0.90	2.44	0.95	3.38	753,800
08	18.1	0.5	10.1	0.25	0.62	0.28	0.88	293,300
09	36.8	2.1	23.5	0.62	1.66	0.67	2.31	586,900
10	31.2	1.8	18.3	0.53	1.41	0.58	1.97	444,400
11	8.2	1.9	3.4	0.09	0.19	0.10	0.28	138,200
12	19.0	0.5	10.2	0.47	1.23	0.51	1.72	419,800
13	66.1	10.4	36.3	1.14	3.15	1.21	4.34	719,100
14	11.2	0.7	6.7	0.15	0.36	0.17	0.52	183,600
15	14.8	1.8	7.6	0.31	0.80	0.35	1.13	295,100
16	28.9	0.0	15.2	0.76	2.05	0.81	2.85	633,700
17	27.8	4.3	13.4	0.43	1.13	0.47	1.59	446,900
18	31.1	9.8	16.6	0.62	1.66	0.67	2.31	504,100
Total	**527.6**	**43.3**	**287.9**	**10.5**	**28.0**	**11.2**	**39.0**	**9,035,600**

a. Peak storage calculations are based on the 25-year design storm event; overflow outlet dimensions were adjusted such that the 25-year peak water surface elevations coincide with a depth of 3 feet.

b. Surface area associated with water ponding at a depth of 3 feet (i.e., the 25-year peak water surface).

c. Storage volume within the facility at 3 feet depth (i.e., peak storage from the 25-year event).

d. The top of the regional stormwater facility corresponds to a 4-foot depth, which includes 1 foot of freeboard above the 25-year peak water surface elevation.

e. Surface area associated with the internal storage volume at 4-foot depth. This does not include areas for berm or grading.

f. Storage volume within the facility at the 4-foot depth; total required storage volume for the facility (including freeboard).

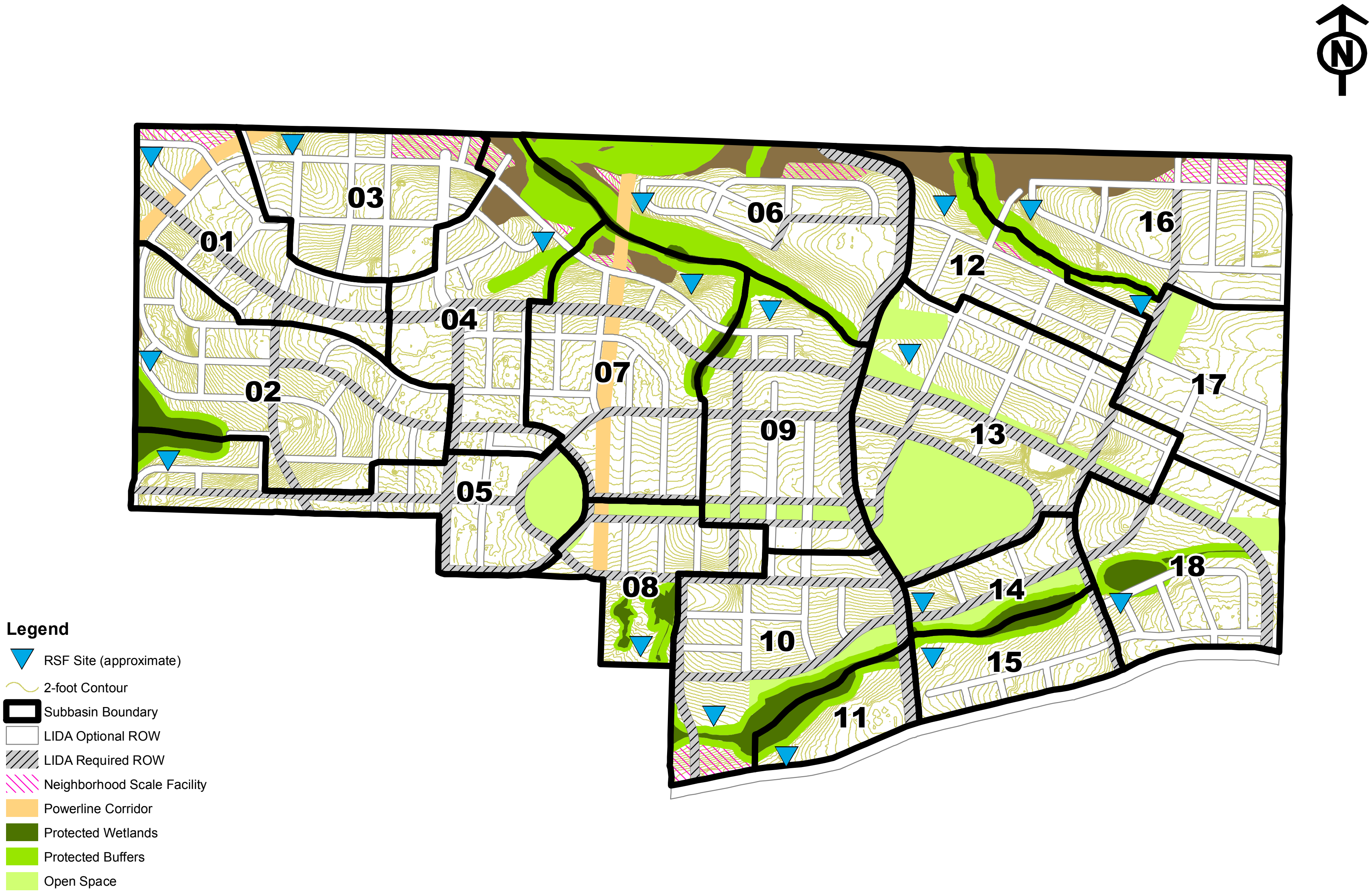
g. Costs are based on ENR 20-city average construction cost index (CCI) = 9,070; land acquisition costs are not included.

h. Costs for subbasin No. 13 do not include wetland mitigation and permitting costs. These costs are estimated at $56,000.

4/30/2013

Path: P:\Clean Water Services\North_Bethany_Basin_Plan\Peak_Matching_Standard\GIS\MXD\NB_RSF_Sizing_FigES-1.mxd

Author: NFoged



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500 0 500 FT

1 inch = 1,000 feet

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FIGURE ES-1

SUBBASINS FOR REGIONAL STORMWATER FACILITIES

North Bethany Stormwater Implementation Plan
SBUH Analysis for Regional Stormwater Facility Sizing and Costing

Section 1

Introduction

North Bethany is a land use planning subarea within unincorporated Washington County, Oregon (County). In 2002, the Portland metropolitan Urban Growth Boundary (UGB) was expanded to include the North Bethany area. Since that time, the County and Clean Water Services (District) have been conducting planning efforts to guide future development within the North Bethany area.

The *North Bethany Subarea Drainage Master Plan* (DMP) was completed by Otak in 2010. The purpose of the DMP was to describe general strategies and conceptual designs for stormwater management. The DMP was referenced in Washington County Ordinance 730-A, which was adopted in July 2010.

The District contracted with Brown and Caldwell (BC) to develop the *North Bethany Stormwater Implementation Plan: SBUH Analysis For Regional Stormwater Facility Sizing and Costing* (Plan). Building on the DMP, the Plan incorporated revised land use designations and development criteria as described in Washington County Ordinance 739-A, which was adopted in October 2011.

Purpose and Objectives. In March 2013, BC provided quality control review of the stormwater management concepts presented in the DMP and developed recommendations for regional stormwater facilities (RSFs) designed to mitigate peak discharges in accordance with the District's current standards. This Plan describes BC's analysis and provides RSF sizing and project costing information. The following objectives were achieved:

- describe the analytical methods and assumptions used to perform the sizing calculations
- summarize the RSF sizes along with key design assumptions
- provide updated RSF concept-level cost estimates

Section 2

Background

The North Bethany planning area covers approximately 674 acres of unincorporated Washington County[1], located north of NW Springville Road between NW 185th Avenue and NW 145th Avenue (see *Plan Area and Vicinity*, Appendix A-1). Note that the Arbor Oaks development and Portland Community College were not analyzed as part of this plan.

The following sections provide background information regarding relevant land use ordinances, design standards, and requirements for low-impact development approaches (LIDA).

2.1 North Bethany Land Use Ordinances

After the North Bethany area was added to the UGB in 2002, the County began preparing the *North Bethany Concept Plan* (Concept Plan) to establish a vision and framework for how new development would occur in the North Bethany Area. The Concept Plan was adopted and subsequently revised through a series of ordinances, described on the Washington County Web site[2] as follows:

- **A-Engrossed Ordinance 712 (adopted October 27, 2009; effective November 27, 2009):** Adopted the Concept Plan for North Bethany, and provided a basis for subsequent work to address implementation mechanisms.
- **A-Engrossed Ordinance 730 (adopted October 26, 2010; effective November 26, 2010):** Adopted implementing regulations for North Bethany, including urban land use districts and development code standards.
- **A-Engrossed Ordinance 739 (adopted October 25, 2011; effective November 25, 2011):** Adopted refinements to the concept plan and implementing regulations. Key provisions included new standards for urban/rural compatibility, building variety and design, road landscape maintenance, and clarifying standards for development on density restricted lands.
- **A-Engrossed Ordinance 744 (adopted April 24, 2012; effective May 24, 2012):** Adopted refinements to the concept plan and implementing regulations. Key provisions included a new Area of Special Concern for Primary Street P16, map amendments for the locations of Primary Streets P15 and P16, and clarifications on the provisions for gateways.
- **A-Engrossed Ordinance 745 (adopted June 26, 2012; effective July 26, 2012):** Adopted refinements to the concept plan and implementing regulations. Key provisions included new Areas of Special Concern for two multifamily residential sites; plan provisions for modification to alignment of primary streets; modification to plan amendment criteria; new development standards for cluster housing, adjusting land use district boundaries, Planned Developments, and alternative partition standards for the conveyance of land for parks and stormwater facilities.

The land use mapping and road right-of-way mapping based on Ordinance 739-A served as the basis for the analyses included in this plan; however, the following changes were made:

- Revised road right-of-way alignments near Primary Street P15, based on proposed North Bethany Creek Subdivision (scanned map provided via e-mail by Carrie Pak, March 7, 2013).

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[1] Excluding the Portland Community College and Arbor Oaks areas results in a total area for all 18 subbasins of 620 acres.

[2] http://www.co.washington.or.us/LUT/PlanningProjects/Bethany/#AnchorA712

- Revised road right-of-way alignments in southeast corner of planning area, based on proposed subdivision by Polygon Northwest Company (scanned map provided via e-mail by Carrie Pak, March 7, 2013).
- Road right-of-way areas were designated as either “LIDA Required” or “LIDA Optional” based on mapping in Figure 2 of the DMP (Otak 2010).

Proposed Land Use and LIDA Requirements (Appendix A-2) shows the proposed land uses and road rights-of-way for the entire North Bethany planning area.

2.2 Stormwater Design Standards

Development standards for surface water management are set forth by the District and described in the *Design and Construction Standards for Sanitary Sewer and Surface Water Management* (D&C Standards, 2007). The District also encourages the use of LIDA and has developed a supplement to the D&C Standards titled *Low Impact Development Approaches Handbook* (July 2009). BC reviewed the current standards for water quality treatment and water quantity control; the following sections summarize the standards and design criteria relevant to this plan.

2.2.1 Water Quality Treatment

The District requires new impervious surfaces to be treated through permanent water quality facilities designed to reduce contaminants entering the stormwater and surface water system. The following bullets describe some of the key D&C Standards related to stormwater quality treatment for new development:

- Water quality treatment is required by the District for the creation of new impervious surface unless the development is for the construction of one or two family (duplex) dwellings on an existing lot of record (D&C Standards, Section 4.05).
- The District’s design storm for water quality facilities is a dry weather storm event totaling 0.36 inch of precipitation falling in 4 hours with an average storm return period of 96 hours (D&C Standards, Section 4.05.4d).
- The water quality volume (WQV) is the volume of water that is produced by the water quality storm. The WQV equals 0.36 inch over the impervious area that is required to be treated as shown in the formula below (D&C Standards, Section 4.05.6b):

$$WQV = \frac{0.36\ (in.) \times Area(sq\ ft)}{12\ (in./ft)}$$

- The water quality flow (WQF) is the average design flow anticipated from the water quality storm as shown in the formulas below (D&C Standards, Section 4.05.6c):

$$WQF = \frac{0.36\ (in.) \times Area(sq\ ft)}{(12\ in./ft)(4\ hr)(60\ min/hr)(60\ sec/min)}$$

2.2.2 Water Quantity Control

The District requires stormwater runoff to be managed through permanent flow control facilities designed to reduce discharges entering the stormwater and surface water system. The following bullets describe some of the key D&C Standards related to water quantity control for new development:

- Post-development runoff rates must match pre-development runoff rates for peak discharges produced by 24-hour design storms with recurrence intervals of 2, 10, and 25 years (D&C Standards, Section 4.03.4b); mitigation can be accomplished through the construction of detention facilities.

- Detention design shall be assessed by dynamic flow routing through the storage basin using runoff hydrographs generated using Santa Barbara Urban Hydrograph (SBUH) or Technical Release 55 (TR-55) methodologies (D&C Standards, Section 4.03.3a).
- Computational methods for runoff calculations using the SBUH or TR-55 methods shall be based on the following information (D&C Standards, Section 5.04.2b):
  - The rainfall distribution to be used within the District is the design storm of 24-hour duration based on the standard National Resources Conservation Service (NRCS) Type 1A rainfall distribution using the chart in Standard Details CA-3.
  - Curve numbers shall be derived from the NRCS runoff curve numbers contained in the TR-55 document (USDA 1986).
  - Soil types shall be derived from the NRCS Soil Survey for Washington County.

Although the RSFs evaluated for this plan will provide water quality treatment, the size of the facilities will be governed by the storage capacity needed to provide adequate water quantity control.

The SBUH method was used to size RSF. Section 3 of the Plan provides a detailed discussion of the SBUH analysis.

2.2.3 Low-Impact Development Approaches (LIDA)

The District encourages the use of LIDA to reduce the impacts of urban stormwater runoff. Although LIDA are primarily used for water quality treatment, some LIDA facilities can also provide water quantity control benefits through storage and infiltration. The District's surface water management standards allow LIDA to be used alone, or in combination with more traditional stormwater control facilities, to meet water quality treatment and/or water quantity control requirements (D&C Standards, Sections 4.03.4d and 4.07.2a).

The District's LIDA handbook describes the use of porous pavement, green roofs, infiltration planters/rain gardens, flow-through planters, LIDA swales, vegetated filter strips, vegetated swales, extended dry basins, and constructed wetlands. All of these facilities address water quality treatment; however, some, such as infiltration planters, can also be used to reduce runoff volumes and provide supplemental water quantity control.

Washington County Ordinance 739-A requires onsite LIDA to be used for the following land uses in the North Bethany Subarea:

- Institutional (INST NB)
- Residential 12–15 units/acre (R-15 NB)
- Residential 19–24 units/acre (R-24 NB)
- Residential 20–25 units/acre (R-25+ NB)
- Neighborhood Commercial Mixed Use (NCMU NB)
- Neighborhood Corner Commercial (NC NB)

Onsite LIDA is considered optional for land uses not listed above (e.g., residential 5–6 units/acre). As a conservative assumption for this analysis, LIDA was assumed to be implemented only for the required areas. The RSFs can easily be re-sized to accommodate LIDA implementations, if necessary. *Proposed Land Use and LIDA Requirements* (Appendix A-2) shows the areas within North Bethany where LIDA is required.

For street LIDA, Figure 2 in the DMP (Otak 2010) identifies road rights-of-way where LIDA are required. Accordingly, the street areas that are shaded gray in Figure 2 of the DMP have been designated "LIDA-Required ROW." The street areas shown in white in Figure 2 of the DMP have been designated "LIDA-Optional ROW."

Section 3

Analysis

RSFs were sized according to the District's standards for mitigating water quantity using extended dry basins (D&C Standards, Sections 4.03.4 and 5.04.2). The basic steps involved in this analysis are as follows:

1. Delineate the drainage subbasin for each RSF.
2. Map the soils and land cover for both pre-development and post-development conditions.
3. Calculate runoff hydrographs for pervious and impervious surfaces using the SBUH method.
4. Route the runoff from LIDA-required impervious areas through a LIDA facility.
5. Route the total combined post-development hydrograph through an extended dry basin using level-pool routing techniques.
6. Compare pre-development and post-development peak discharges and iteratively adjust the size of the facility until the mitigation requirements are achieved.

The following subsections describe the calculation methods and assumptions. Results from the analysis are presented in Section 4.

3.1 Subbasin Delineation

The North Bethany plan area (excluding Arbor Oaks and the Portland Community College) was divided into subbasins for stormwater management. Each subbasin represents the area controlled by a single RSF; however, not all areas within a particular subbasin will drain to the RSF. In other words, subbasins include both contributing and non-contributing areas. Non-contributing areas are undevelopable lands, typically located down-gradient from the RSF. For example, wetlands are considered "non-contributing" because they are protected lands, and an RSF would likely be located up-gradient such that the wetland areas would not drain to the facility. Some of the subbasins also contain developable areas that cannot be drained to the RSF due to topographic constraints; these areas cannot be managed by the RSF and must be managed using onsite or neighborhood-scale facilities.

The DMP (Otak 2010) subbasins were used as a starting point for this analysis. However, several adjustments were then made based on feedback from District staff. Revisions to the subbasins were based on the following:

- Subbasin boundaries were adjusted to be more consistent with topography, proposed land uses, and road rights-of-way.
- Small subbasins were consolidated into larger subbasins where reasonable to do so.
- Subbasins in the southwest corner of the North Bethany area were adjusted to accommodate the proposed subdivision by Polygon Northwest Company (scanned map provided via e-mail by Carrie Pak, March 7, 2013).
- Subbasins in the south-central portion of the North Bethany area were adjusted to accommodate the proposed North Bethany Creek Subdivision (scanned map provided via e-mail by Carrie Pak, March 7, 2013).

Subbasin Delineations for Regional Facilities (Appendix A-3) shows the revised subbasins. Calculated subbasin areas are provided in *Subbasin Areas and Imperviousness* (Appendix B-1).

3.2 Soils and Land Cover Mapping

The amount of runoff generated by a drainage area depends on soil and land cover characteristics. Geospatial data were used to develop maps with soil types and land cover categorizes for pre-development and post-development conditions.

3.2.1 Hydrologic Soil Groups

The NRCS classifies soils according to the potential to generate runoff, or inversely, their relative capacities for infiltration and transmission of rainfall. NRCS (1986) defines four groups as follows:

- **Group A** soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 inch per hour).
- **Group B** soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 inch per hour).
- **Group C** soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05 to 0.15 inch per hour).
- **Group D** soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 inch per hour).

NRCS Hydrologic Soil Groups (Appendix A-4) shows the spatial distribution of hydrologic soil groups based on the NRCS Soil Survey for Washington County (NRCS, 1982). Approximately 80 percent of the North Bethany plan area is mapped as Group C soils and 20 percent as Group D soils. The Group D soils are located primarily in stream corridors and wetland areas. For the purposes of this analysis, the distribution of soil groups for post-development conditions was assumed to be the same as for pre-development conditions.

3.2.2 Pre-Development Land Cover

Ortho-imagery from the National Agriculture Imagery Program (NAIP) was obtained through the National Map data server[3]. An NAIP survey conducted in 2010 produced near-infrared aerial images of the North Bethany area with a grid resolution (i.e., pixel size) of 15 centimeters, or approximately one-half foot. These images were used to analyze pre-developed land cover because the image files contain intrinsic data for four color bands: red, green, blue, and near-infrared. The first three are the typical color ranges used to display true color images (see *2010 Aerial Photography True Color*, Appendix A-5). The fourth, near-infrared band can be used to assess vegetative cover (see *2010 Aerial Photography Near-Infrared*, Appendix A-6). The numerical color values can be used to quantitatively evaluate the density of vegetation using a Normalized Difference Vegetation Index (NDVI):

$$NDVI = \frac{NIR - VIS}{NIR + VIS}$$

where: *NIR* = spectral reflectance measurement for the near-infrared band

VIS = spectral reflectance measurement for the visual red band

NDVI values were parsed into five land cover categories as described in Table 3-1.

[3] http://nationalmap.gov/

Table 3-1. Pre-Development Land Cover Categories		
NDVI range	**Vegetative cover**	**Land cover category**
NDVI < 0	None	Open water
0 < NDVI < 80	None	Impervious surfaces or compacted earth
80 < NDVI < 220	Low	Low cover crop land
220 < NDVI < 420	Moderate	Grassland or prairie
420 < NDVI	High	Woodland

The calculated NDVI values and pre-development land cover categories were used to develop a geospatial grid representing the pre-developed conditions plan area (see *Pre-developed Land Cover Mapping*, Appendix A-7).

3.2.3 Post-Development Land Cover

Land cover categories for post-development conditions were based on North Bethany land use planning categories as discussed previously, and shown in *Proposed Land Use and LIDA Requirements* (Appendix A-2). An assumed percent imperviousness was assigned to each post-development land cover category (see Table 3-2).

Table 3-2. Post-Development Land Cover Categories and Imperviousness	
Land cover category	**Percent imperviousness**
Institutional (INST NB)	35
Residential 5–6 units/acre (R-6 NB)	45
Residential 7–9 units/acre (R-9 NB)	50
Residential 12–15 units/acre (R-15 NB)	60
Residential 19–24 units/acre (R-24 NB)	65
Residential 20–25 units/acre (R-25+ NB)	80
Neighborhood Corner Commercial (NC NB)	80
Neighborhood Commercial Mixed Use (NCMU NB)	82
Road Right-of-Way	71
Open Space	35
Protected or Restricted Areas[a]	0

a. Includes power line easements, wetlands, buffers, and forested areas/sleep slopes.

Calculated impervious areas for each subbasin are provided in *Subbasin Areas and Imperviousness* (Appendix B-1).

3.3 SBUH Runoff Routing

The SBUH method was developed by Stubchaer (1975) for the Santa Barbara Flood Control and Water Conservation District. It is largely similar to commonly used event-based methods developed by the Soil Conservation Service (SCS); however, the SBUH method does not use a unit hydrograph to transform excess precipitation to runoff rates. Alternatively, the SBUH method creates an instantaneous runoff hydrograph, which is then routed through a hypothetical reservoir that causes a time delay equal to the time of concentration (Akan, 1993). Details regarding SBUH input data and computations are provided below.

3.3.1 Rainfall Hyetographs

The SBUH method uses 24-hour design storm events. Rainfall depths for 24-hour events with various recurrence intervals were obtained from Drawing 1280 of the District's D&C Standards (see Table 3-3).

Table 3-3. 24-Hour Rainfall Depths

Recurrence interval (years)	Precipitation depth (inches)
2	2.50
5	3.10
10	3.45
25	3.90
50	4.20
100	4.50

The total rainfall depths were distributed using an NRCS Type 1A distribution. Although Drawing 1285 of the D&C Standards tabulates incremental and cumulative rainfall rates for the NRCS Type 1A distribution, the data are hourly. In order to capture the most intense rainfall rates, which occur over smaller time increments in the relatively small basins in the North Bethany area, a more detailed tabulation of the NRCS Type 1A distribution with 6-minute time increments was obtained from TR-20 (USDA, 1992). Figure 3-1 compares the hourly and 6-minute distributions using a normalized rainfall intensity (i.e., the incremental percentage of rainfall divided by the time increment).

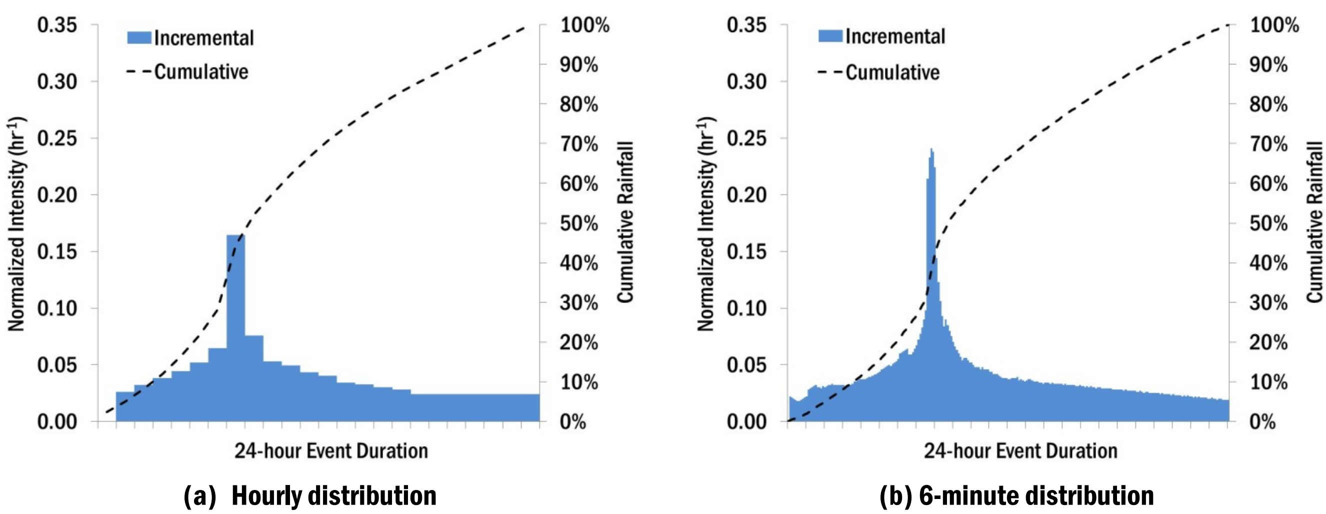


Figure 3-1. Comparison to NRCS Type 1A distributions with different time increments

(a) Hourly time increments from Drawing 1285; (b) 6-minute time increments from TR-20

Figure 3-1 illustrates how the peak rainfall rate from a 6-minute distribution produces a more intense peak than an hourly distribution. This is particularly important in a small basin where the time of concentration is less than 1 hour; this is the case for all of the North Bethany subbasins. Therefore, the 6-minute distribution was used for this evaluation. Design storm hyetographs are provided in *NRCS Type 1A Rainfall Distribution* (Appendix C-1).

3.3.2 Curve Number Selection

Excess precipitation (i.e., the amount of rainfall that becomes runoff) was calculated using the SCS Curve Number method, which uses the following equation from NRCS TR-55 (USDA 1986):

$$P_e = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where:
P_e = excess precipitation/runoff (inches)
P = precipitation (inches)
I_a = initial abstraction (inches)
S = retention storage (inches)

The initial abstraction value, I_a, is the amount of water lost before any runoff is generated, primarily due to interception storage, depression storage, and infiltration. The retention storage value, S, is the potential maximum retention within the watershed after runoff begins. Both I_a and S are closely related to the vegetative cover and the soil type within the watershed, which can be represented through a curve number, *CN*. The retention storage value, S, is calculated in NRCS TR-55 (USDA 1986) as follows:

$$S = \frac{1000}{CN} - 10$$

The initial abstraction value, I_a, is often estimated as a fraction of S. That fraction, denoted λ, is often assumed to be 0.2, based on empirical data for small agricultural watersheds (USDA 1986).

Table 2-2 of the NRCS TR-55 document (USDA 1986) was used to select curve numbers for each combination of hydrologic soil group and land cover identified within the North Bethany area (see Table 3-4).

Table 3-4. Selected Curve Numbers

Scenario	Land cover description	Curve number		Reference to TR-55 (USDA 1986)
		Group C soils	Group D soils	
Pre-Development	Open water	98	98	Assumed to be equivalent to impervious areas
	Impervious surfaces or compacted earth	98	98	Table 2-2a, impervious surfaces
	Low cover crop land	88	91	Table 2-2b, straight row crop, poor condition
	Grassland or prairie	79	89	Table 2-2c, grassland, fair/good condition
	Woodland	73	79	Table 2-2c, woods, fair condition

Table 3-4. Selected Curve Numbers				
Scenario	Land cover description	Curve number		Reference to TR-55 (USDA 1986)
		Group C soils	Group D soils	
Post-Development	All developed impervious areas	98	98	Table 2-2a, paved impervious areas
	Institutional (pervious areas only)	79	84	Table 2-2a, grass open space, fair condition
	Commercial [a] (pervious areas only)	79	84	Table 2-2a, grass open space, fair condition
	Road right-of-way (pervious areas only)	84	89	Table 2-2a, grass open space, poor condition
	Open space (pervious areas only)	74	80	Table 2-2a, grass open space, good condition
	Power line easement	74	80	Table 2-2a, grass open space, good condition
	Wetlands [b]	86	89	Table 2-2a, grass open space, poor condition
	Wetland buffer [b]	74	80	Table 2-2a, grass open space, good condition
	Forested/steep slopes [b]	70	77	Table 2-2c, woods, good condition

a. Includes Neighborhood Corner Commercial and Neighborhood Commercial Mixed Use.

b. Protected or restricted areas are not developed and are usually considered non-contributing areas.

Area-weighted composite curve numbers were calculated for each subbasin area generating runoff. Areas were calculated using geospatial raster data sets developed from the soils and land cover data described in Subsection 3.2.

3.3.3 Runoff Routing Formula

The curve number equations described in the previous section were used to calculate incremental runoff depths for each time increment in the design storm hyetograph. These values were then multiplied by the drainage area and divided by the time step to obtain the instantaneous hydrograph as follows:

$$I_j = \frac{R_j A}{\Delta t}$$

where:
- I_j = instantaneous hydrograph for time increment *j*
- R_j = runoff depth for time increment *j*
- A = contributing drainage area
- Δt = time increment

The instantaneous hydrograph is then routed to obtain runoff rates using the following equations:

$$Q_j = Q_{j-1} + K(I_{j-1} + I_j - 2Q_{j-1})$$

$$K = \frac{\Delta t}{2T_c + \Delta t}$$

where:
- Q_j = discharge for time increment *j*
- Q_{j-1} = discharge for previous time increment, *j-1*
- I_j = instantaneous hydrograph for time increment *j*
- I_{j-1} = instantaneous hydrograph for previous time increment, *j-1*
- Δt = time increment
- K = routing constant
- T_c = time of concentration, sum of all travel times

Calculated peak discharges for pre-development and post-development conditions are provided in *Peak Discharges for Design Storm Events* (Appendix B-2).

3.4 Adjusting for LIDA

Where required, developed impervious areas will drain to LIDA facilities. These facilities are often used for water quality treatment; however, some types of LIDA can also reduce runoff quantity through storage and infiltration. For example, stormwater runoff from impervious surfaces can be routed to infiltration planters where the water can be stored in the drain rock, growing medium, and ponding layers; in addition, water can be infiltrated into the surrounding soils through the bottom of such facilities. However, it should be noted that soils in the North Bethany area tend to be poorly drained soils with relatively low infiltration rates. As described in Section 3.2.1, hydrologic soil groups C and D cover roughly 80 percent and 20 percent of the plan area, respectively. According to the USDA (1986) estimated ranges for the infiltration rates of water transmission through Group C and Group D soils are as follows:

- Hydrologic Soil Group C: 0.05 to 0.15 inches per hour
- Hydrologic Soil Group D: 0.0 to 0.05 inches per hour

For the purposes of this analysis, infiltration planters, as described in Detail 793 of the LIDA Handbook (2009), were assumed to be used to treat runoff from all LIDA-required impervious areas (no LIDA facilities were assumed for the LIDA-optional areas). According to the LIDA Handbook, infiltration planters shall have a footprint area equal to 6 percent of the impervious area draining to it. This factor was used to size an aggregate facility for each subbasin modeled in this analysis. The average infiltration rate for the infiltration planter was assumed to be 0.1 inch per hour, which is the midpoint of the range for Group C soils (USDA 1986). Additional design criteria obtained from the LIDA Handbook are listed in Table 3-5.

Table 3-5. Infiltration Planter Design Criteria (LIDA Manual Drawing 793)

Design criterion	Value
Footprint area	6% of the impervious drainage area
Ponding depth, inches	6
Growing media depth, inches	18
Drain rock depth, inches	12
Freeboard depth, inches	2
Side slopes	Vertical
Effective porosity of growth media	0.41
Effective porosity of drain rock	0.42
Infiltration rate [a], inches per hour	0.10

a. The assumed infiltration rate was based on the midpoint of the long-term transmission rate range for Group C soils provided in TR-55 (USDA 1986).

Runoff hydrographs were routed through the infiltration planter using standard level-pool routing techniques (see Section 3.3.3 for details). Results from the routing show that, in general, LIDA facilities like an infiltration planter capture and detain/infiltrate a portion of the runoff volume from the rising limb of the inflow hydrograph. This reduces the volume of runoff reaching the RSF, which in turn reduces the size of the RSF needed to mitigate peak discharges.

Infiltration planters, or LIDA demonstrating equivalent performance (storage and infiltration), must be implemented for impervious surfaces within LIDA-required areas to achieve the RSF sizes recommended at the end of this document. LIDA facilities that do not provide an equivalent amount of storage and/or infiltration will require a larger RSF. Similarly, larger LIDA facilities, or implementation of LIDA in LIDA-optional areas, could reduce the size of the RSF. Either case would require new analyses to demonstrate that peak discharges are mitigated in accordance with the D&C Standards (2007).

Calculated peak discharges with and without LIDA are provided in *Peak Discharges for Design Storm Events* (Appendix B-2). LIDA design concepts from the DMP are illustrated in Appendix D.

3.5 Peak Flow Mitigation

Runoff hydrographs from the pervious area, impervious areas draining to LIDA, and impervious areas without LIDA were combined into one post-development runoff hydrograph for each subbasin. The total runoff hydrograph was then routed into an RSF represented by an “extended dry basin” as described in Section 4.06.3 of the D&C Standards (2007).

3.5.1 Design Criteria for an Extended Dry Basin

Where possible, design criteria were kept consistent with those used to design RSFs for the DMP (Otak 2010). For this analysis, all RSFs were assumed to be circular/rectangular facilities; no linear configurations were used. Preliminary analyses using unsteady-flow hydraulic modeling suggested that linear configurations tended to require larger facilities to achieve the peak-matching criteria. In short, the linear facilities are not as efficient at utilizing storage for peak attenuation as circular and rectangular facilities. Therefore, circular/rectangular configurations were assumed for all locations.

The following design criteria were used for modeling an extended dry basin:

- **Permanent pool depth:** A permanent pool depth was not included in the storage requirement. This conservative assumption allows for the permanent pool to be replaced with amended soils and drain rock to promote infiltration and plant growth.
- **Facility depth:** RSFs were designed with a maximum available storage depth of 4 feet; this includes 1 foot of freeboard (Figure 3-2). District staff has found that native wetland plantings survival rates are optimized with a maximum facility depth of 3 feet. The D&C Standards specify that freeboard is measured as the depth above the 25-year water surface elevation. Given that the outflow discharges from the facility will vary, the outlet configuration will need to be designed to maintain sufficient capacity without infringing upon the freeboard requirement (see discussion of outlet design below).
- **Sedimentation forebays:** Facilities were modeled as single cells; sedimentation forebays were replaced with water quality manholes as requested by District staff.
- **Interior side slopes:** The interior side slopes were assumed to be 3 horizontal to 1 vertical (3:1) for all sides up to the maximum depth of the facility, including the freeboard depth.
- **Water quality volume:** The water quality volume was calculated for each RSF; however, the storage volume required to attenuate peak runoff rates always exceeded the water quality volume and was the controlling design parameter.

In addition, an outlet structure was designed to control outflow from the RSF. The District’s D&C Standards refer to Drawing 720 and Drawing 730 for design of an outlet control structure. Figure 3-3 shows the detail from Drawing 720.

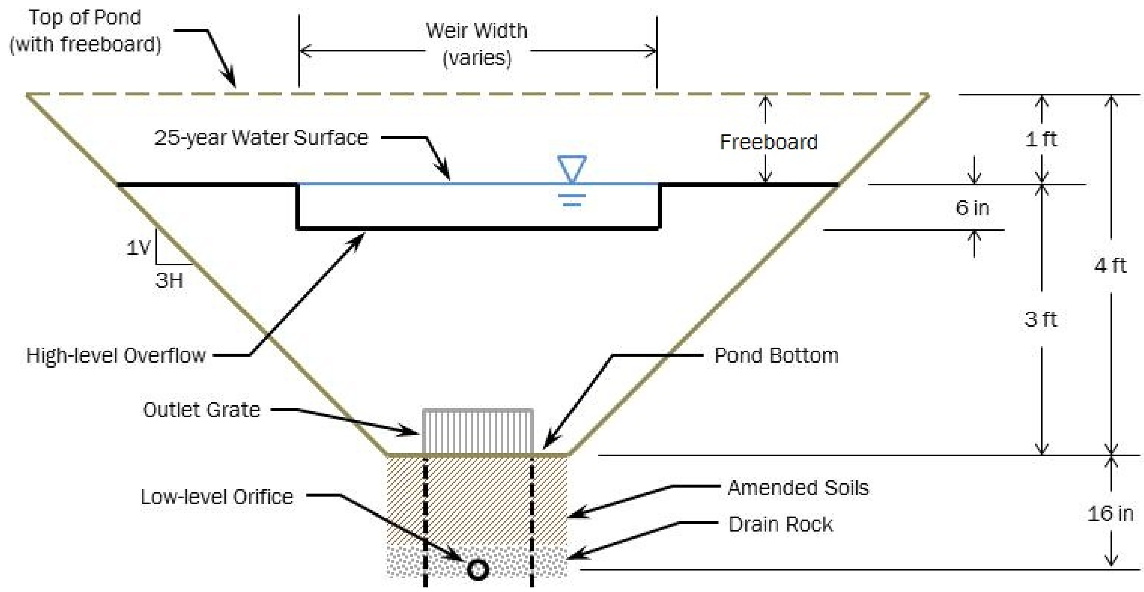


Figure 3-2. Conceptual sketch of pond depth and outlet elevations

Not to scale.

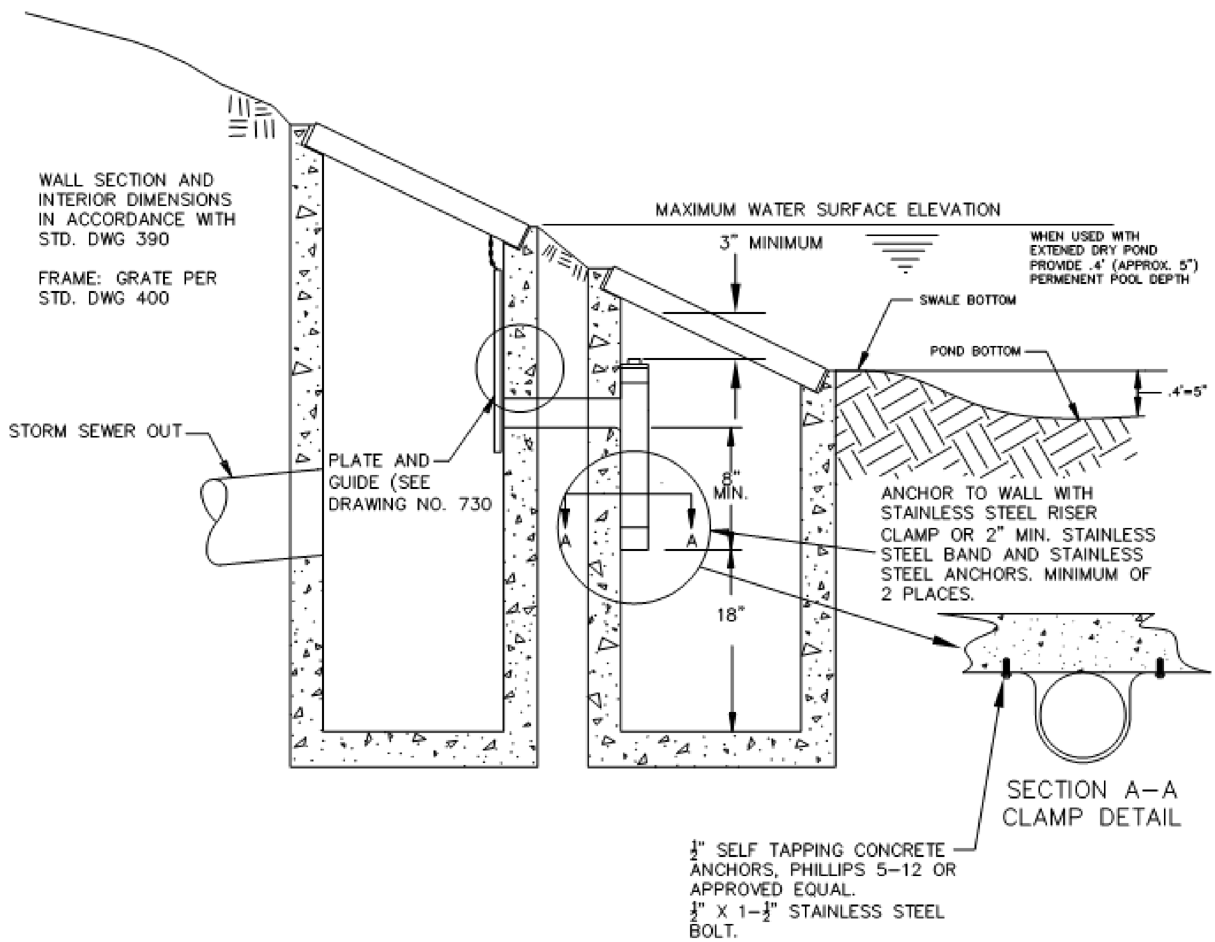


Figure 3-3. Outflow control structure standard detail

Drawing 720 from D&C Standards (District, 2007)

The outlet structure shown in Drawing 720 (Figure 3-3 above) consists of two grated ditch inlets connected by a pipe and an orifice plate. The first ditch inlet is set at the pond bottom; as the pond begins filling, water spills into the first ditch inlet allowing water to discharge through the outflow pipe/orifice (see description of "low-level orifice outlet" below). The second ditch inlet is set at a higher elevation to regulate high flow rates (see description of "high-level overflow outlet" below).

Low-Level Orifice Outlet

The low-level orifice for each regional detention facility was set 16 inches below the bottom of the pond. The diameter of the orifice was calculated based on the sizing equations provided in Section 4.06.3a of the D&C Standards:

$$D = 24\left[\frac{Q_a}{C\sqrt{2gH}}\frac{1}{\pi}\right]^{0.5}$$

$$Q_a = \frac{WQV}{48 * 60 * 60}$$

where:
- D = diameter of orifice (inches)
- Q_a = average outflow required to evacuate the WQV over 48 hours
- C = discharge coefficient = 0.62
- H = (2/3) x head over the orifice at the peak design water surface elevation
- g = gravitational constant

Note that for maintenance purposes, orifices size was limited to a minimum diameter of 2 inches. The calculated orifice diameter was less than, or approximately equal to 2 inches for all RSFs except for the RSF for Subbasin 18, which was estimated to be 2.5 inches.

Orifice flow was calculated using the following equation:

$$Q_{orifice} = C_d A\sqrt{2gH}$$

where:
- $Q_{orifice}$ = outflow through the orifice
- C_d = discharge coefficient = 0.62
- A = area of the orifice
- g = gravitational constant
- H = head over the orifice (assume free flow)

High-Level Overflow Outlet

The District's D&C Standards call for the top of a ditch inlet to be covered with a grate as shown in Drawing 390. This grate provides a width of 27 inches; however, the bars of the grate reduce the effective width to approximately 24 inches. Preliminary modeling found that this width is not large enough to pass peak flows from the 25-year storm event without overtopping the facility. Therefore, the high-level overflow was modeled like an open weir. In design, multiple ditch inlets lined up side-by-side could be used to achieve the open weir effect.

As mentioned previously, runoff rates from the 25-year storm event vary for each RSF. As such, either the weir elevation or the weir width has to be adjusted to maintain the 4-foot pond depth and 1-foot freeboard specified at the beginning of this section. For this analysis, the height of the weir was set at a constant 2.5 feet above the pond bottom for all facilities. The weir width was then iteratively adjusted to pass the mitigated 25-year outflow with 0.5 foot of head.

Weir flow was calculated using the following equation:

$$Q_{weir} = \frac{2}{3} C_d L \sqrt{2g} H^{3/2}$$

where: Q_{weir} = outflow through the weir

C_d = discharge coefficient = 0.60

L = length of the weir

g = gravitational constant

H = head over the weir

3.5.2 Level Pool Routing

Level pool routing is a computational procedure for calculating the outflow from a storage reservoir with a horizontal water surface, given stage-storage-outflow characteristics. A detailed procedure is presented by Chow et al. (1988) using the following routing equation:

$$\left(\frac{2S_{j+1}}{\Delta t} + O_{j+1}\right) = \left(I_j + I_{j+1}\right)\left(\frac{2S_j}{\Delta t} - O_j\right)$$

where: O_j = outflow discharge for time increment *j*

O_{j+1} = outflow discharge for next time increment, *j+1*

I_j = inflow hydrograph for time increment *j*

I_{j+1} = inflow hydrograph for next time increment, *j+1*

S_j = facility storage for time increment *j*

S_j = facility storage for next time increment, *j+1*

Δt = time increment

Calculated peak mitigated outflows are provided in *Peak Discharges for Design Storm Events* (Appendix B-2).

Section 4

RSF Sizing and Costing Results

Rainfall-runoff and routing analyses described in the previous section were used to size RSFs designed to mitigate post-development peak flow to match pre-development peak flows for the 2-, 10-, and 25-year storm events. The basic size requirement for each RSF is typically measured in terms of the surface area and/or the storage volume. Surface areas and storage volumes were calculated at three levels:

- **Depth to contain the WQV:** The WQV was calculated as described in Section 2.2.1; the numbers are presented for informational purposes only. The WQV is always less than the volume needed to meet water quantity control criteria. Therefore, the size of the facility depends on the water quantity control requirements.
- **3-foot depth:** RSFs were sized to pass the 25-year design storm event with the peak water surface at 3 feet, given the outlet configuration described in Section 3.5.1. Other design events (e.g., the 2- and 10-year events) require smaller volumes; therefore, the 25-year event is the determining factor.
- **4-foot depth:** An additional 1-foot of depth is provided above the 25-year peak water surface elevation to account for freeboard requirements. This is the top of the facility.

Key design criteria and estimated sizing requirements for each subbasin are provided in *Regional Stormwater Facility Sizing Results* (Appendix B-3).

Construction costs for the RSFs are shown in Table 4-1.

The estimated construction cost estimates are based on the following assumptions:

- Facilities will be located in relatively the same locations as proposed in the DMP.
- Facility configuration for all facilities is round. Linear or multi-cell facilities were determined by this analysis to be much larger and therefore infeasible.
- Fixed capital costs, such as control structures, conveyance pipe, rock weirs, and energy dissipation pads were based on unit costs developed specifically for this project. The unit costs are show in *Unit Costs for Estimating RSF Costs* and *Pipe Unit Costs* (Appendix B-4 and B-5, respectively).
- Total capital costs include mobilization, traffic control and utility relocation, and erosion control. These costs are estimated based on percentages of the capital costs: 10, 2, and 2 percent, respectively.
- A construction contingency is based on 30 percent of the total capital cost.
- The percentage for permitting, engineering, and construction administration is 40 percent of the total capital cost and contingency.

This evaluation compares the total construction cost for RSF construction. Land acquisition, conveyance system costs, and long-term operations and maintenance costs were not included in the evaluation.

A summary of the sizing results and construction cost estimates is presented in Table 4-1. A more detailed summary of the RSF costs is shown in *RSF Detailed Costs* (Appendix B-6).

Table 4-1. Regional Stormwater Facility Sizing and Cost Summary								
Subbasin	Contributing drainage areas			Peak storage[a] (25-year event)		Top of facility[d] (including freeboard)		Estimated cost [g, h] 2012 ($)
	Total contributing (ac)	Pre-developed impervious area (ac)	Post-developed impervious area (ac)	Surface area[b] (ac)	Volume[c] (ac-ft)	Surface area[e] (ac)	Volume[f] (ac-ft)	
01	28.8	1.3	16.1	0.56	1.49	0.60	2.08	462,700
02	43.9	1.3	23.2	1.09	3.00	1.15	4.14	914,400
03	28.1	1.7	15.4	0.68	1.84	0.73	2.56	633,700
04	30.3	2.3	17.2	0.70	1.89	0.75	2.62	579,900
05	32.2	1.4	18.5	0.63	1.70	0.68	2.36	513,600
06	29.9	1.3	14.6	0.52	1.38	0.56	1.93	512,400
07	41.0	0.3	21.5	0.90	2.44	0.95	3.38	753,800
08	18.1	0.5	10.1	0.25	0.62	0.28	0.88	293,300
09	36.8	2.1	23.5	0.62	1.66	0.67	2.31	586,900
10	31.2	1.8	18.3	0.53	1.41	0.58	1.97	444,400
11	8.2	1.9	3.4	0.09	0.19	0.10	0.28	138,200
12	19.0	0.5	10.2	0.47	1.23	0.51	1.72	419,800
13	66.1	10.4	36.3	1.14	3.15	1.21	4.34	719,100
14	11.2	0.7	6.7	0.15	0.36	0.17	0.52	183,600
15	14.8	1.8	7.6	0.31	0.80	0.35	1.13	295,100
16	28.9	0.0	15.2	0.76	2.05	0.81	2.85	633,700
17	27.8	4.3	13.4	0.43	1.13	0.47	1.59	446,900
18	31.1	9.8	16.6	0.62	1.66	0.67	2.31	504,100
Total	**527.6**	**43.3**	**287.9**	**10.5**	**28.0**	**11.2**	**39.0**	**9,035,600**

a. Peak storage calculations are based on the 25-year design storm event; overflow outlet dimensions were adjusted such that the 25-year peak water surface elevations coincide with a depth of 3 feet.

b. Surface area associated with water ponding at a depth of 3 feet (i.e., the 25-year peak water surface).

c. Storage volume within the facility at 3 feet depth (i.e., peak storage from the 25-year event).

d. The top of the regional stormwater facility corresponds to a 4-foot depth, which includes 1 foot of freeboard above the 25-year peak water surface elevation.

e. Surface area associated with the internal storage volume at 4-foot depth. This does not include areas for berm or grading.

f. Storage volume within the facility at the 4-foot depth; total required storage volume for the facility (including freeboard).

g. Costs are based on ENR 20-city average construction cost index (CCI) = 9,070; land acquisition costs are not included.

h. Costs for subbasin No. 13 do not include wetland mitigation and permitting costs. These costs are estimated at $56,000.

Section 5

Conveyance System Layout and Costing Results

The North Bethany plan area is predominantly undeveloped with limited stormwater infrastructure in place. As development occurs, installation of stormwater infrastructure (pipes, manholes, catch basins, open-channel conveyances) will be required.

As part of this Plan, a general stormwater conveyance system network was located and sized to ensure that stormwater can be routed and discharged to the regional stormwater facilities within each subbasin. The stormwater conveyance system was configured in conjunction with the proposed roadway alignments and future land use conditions described in Washington County Ordinance 739. Within each subbasin, the pipe network was designed to convey stormwater runoff from individual catchments and discharge runoff to a centralized location (i.e., the proposed location of the regional stormwater facility for the subbasin) via gravity flow. In addition to gutter flow, the conveyance system includes pipes ranging from 12 to 24 inches in diameter. Sizing of the pipes was based on engineering judgment so that costs could be developed. Manholes were located at pipe bends, junctions, and changes in pipe size and spaced no more than every 500 feet apart, in accordance with the D&C Standards 5.07.

The assumed conveyance system layout is shown in *Conveyance System Layout* (Appendix A-8). The fixed capital costs are shown in Table 5-1. The costs used to calculate the capital costs are based on the unit costs shown in *Pipe Unit Costs* (Appendix B-5). A detailed summary of the conveyance system costs is provided in *Conveyance System Detailed Costs* (Appendix B-6).

Table 5-1. Conveyance System Costs			
Subbasin	Capital expense	Administrative expense	Total construction cost[a, b]
01	346,000	138,000	484,000
02	562,000	224,000	786,000
03	356,000	142,000	498,000
04	489,000	195,000	684,000
05	313,000	126,000	439,000
06	324,000	130,000	454,000
07	680,000	272,000	952,000
08	207,000	82,000	289,000
09	603,000	241,000	844,000
10	415,000	166,000	581,000
11	47,000	18,000	65,000
12	254,000	102,000	356,000
13	798,000	320,000	1,118,000
14	100,000	40,000	140,000
15	101,000	40,000	141,000
16	441,000	176,000	617,000
17	239,000	96,000	335,000
18	170,000	69,000	239,000
Total	6,445,000	2,577,000	9,022,000

a. Land acquisition costs, including appraisals, easements, and related administrative costs, are not included in the above costs.

b. The above costs are for the main trunkline system only (i.e., mainline pipes and manholes). Catch basins, curb inlets, field inlets, laterals, and other miscellaneous structures are not included.

Section 6

Downstream Analysis

The D&C Standards (Chapter 2.04 and Chapter 5.05) require a downstream impact assessment to assess (1) changes in flow from development that adds more than 5,280 square feet of impervious area or (2) changes in flow from development that collects and discharges runoff from more than 5,280 square feet of impervious area. The downstream impact assessment is intended to identify whether capacity and/or condition deficiencies are anticipated for structures downstream of a project site.

An analysis performed as part of the DMP identified the need for detention facilities for areas tributary to Bethany Creek and, due to scope and time limitations, recommended further analyses for areas tributary to Abbey Creek. During the DMP adoption phase, downstream property owners raised concerns regarding the effects of additional runoff resulting from urban development in the North Bethany Subarea. However, a downstream analysis was not performed as part of this Plan because all RSFs were sized to prevent post-developed flows from exceeding the pre-developed condition as per D&C Standards 4.03.4.b.

Furthermore, this Plan confirms that without detention, stormwater runoff from developed properties will be significantly higher than the pre-developed runoff. This increase in flow could result in significant downstream impacts to properties adjoining the creeks. In addition, the steep stream corridors tributary to the creeks raise concerns regarding erosion. Therefore, in accordance with D&C Standards Section 4.03.2, the District is requiring RSFs with detention and water quality treatment capabilities. These facilities are to be located near the RSF sites identified in this Plan unless further analyses can show more practical, economical sitings.

Section 7

Implementation

The purpose of this section is to address implementation of the regional stormwater facilities for the North Bethany plan area including phasing (Section 7.1), maintenance (Section 7.2), and next steps (Section 7.3).

7.1 Phasing

The original concept for regional stormwater facilities presented in the DMP included several continuous linear facilities paralleling the creek and trail systems. For this Plan, it was determined that continuous linear facilities sized in accordance with the District's standards would be impractical. This was due to the relatively large size of the facilities (i.e., space constraints), the land use proposed under Washington County Ordinance 739, and development constraints within the vegetated corridor.

The RSFs described in Section 4 represent refined North Bethany stormwater system design based on the original concepts provided in the DMP. The sizing of the RSFs reflects detailed hydrologic/hydraulic modeling of facilities; grading; and the incorporation of revised parcel boundaries, streets, and development patterns proposed in Washington County's Ordinance 739.

As a result, 18 individual, isolated facilities are proposed. While the original concept was to design the linear facilities as a series of cells such that the facility could be constructed in phases, the 18 RSFs included in this Plan are isolated facilities that are not connected or dependent on each other. Design of 18 individual facilities, as opposed to a fewer number of linear facilities, allows for the RSFs to address development that occurs in phases. As development occurs in an individual subbasin, the facility associated with that subbasin would be constructed. Selection and scheduling of facilities would be based on development pressures, funding availability, permitting, and land acquisition issues, all of which are factors that would drive the development within the associated subbasin. Design of the facilities would include inlet/outlet control structures designed to accommodate D&C Standards. This Plan does not propose having construction of individual facilities based on partial development conditions within the subbasin, as the continual construction and reconstruction of these inlet/outlet control structures and of the facility itself would likely add significantly to the costs.

Given the evolving nature of development proposals and trends, additional future changes to the North Bethany plan area are anticipated. For example, it is currently unknown exactly how much site LIDA will be implemented upstream of the RSFs; road alignments may change, density requirements may be altered, etc. Therefore, the District is allowing for flexibility in design of the RSFs and conveyance system to account for varying degrees of site LIDA application upstream and potential changes to the identified location of each RSF. Specifically, the physical design assumptions and criteria as provided in Section 2.2 will remain as set requirements, but new RSF locations may be considered. Facility sizing (footprint area) may be altered based on application of additional site LIDA.

In addition, this Plan identifies a few subbasins that include areas that cannot drain to the RSFs. For each of these areas the developer is responsible for designing a neighborhood-scale facility that will provide both water quality treatment and water quantity control in accordance with the District's standards. Use of LIDA in these areas is encouraged and may reduce facility sizing.

7.2 Maintenance

The sizing and costing of the RSFs in the North Bethany Area followed the District's D&C Standards for facility sizing and design of inlet and outlet control structures. Therefore, it is assumed that maintenance of these public facilities will occur as part of the District's routine maintenance program for public stormwater facilities. Routine annual maintenance activities include trimming of vegetation, bank maintenance, inlet/outlet maintenance, removal of debris, and visual inspections during the wet season to ensure functionality. Non-routine maintenance (occurring every 5 years) would also be expected to occur as part of the District's program and would include activities such as planting vegetation, reshaping/reconstructing, and silt and sediment removal. Facilities are expected to be viable for approximately 20 years, so rebuilding of the facility shall be expected to occur once during the 25-year life-cycle review.

The District's public facility maintenance program includes four visits per year to treatment facilities. Water quality manholes are also inspected and cleaned twice a year as part of the District's routine maintenance program. Therefore, the water quality manholes designed at the inlet to the regional stormwater facilities would be included in that program and would be cleaned twice per year or more frequently where deemed necessary upon inspection.

The RSFs in North Bethany assumed maintenance access via the adjacent proposed roadways or via the proposed trail system running adjacent to the facilities. Trails that are used for maintenance access will need to be 12 feet wide to meet D&C Standards for access (Section 4.02.4 of D&C Standards). The District specifies a maximum of 10 feet from the maintenance access to the center of the inlet/outlet sumped structures, given the reach associated with the arm of the vactor truck. In some cases, when locating the RSFs, conflicts existed with the trail system alignment (i.e., the RSF overlapped with the proposed trail). These alignments will need to be reconsidered and adjusted as facilities are closer to final design. For some facilities, the trail system is not expected to be close enough for maintenance access. In these cases, a maintenance access road should be included in the facility design and cost estimate.

Maintenance of LIDA in the areas upstream of RSFs should occur according to the District's D&C standards, outlined in the LIDA Handbook. Drawing # 404 in the LIDA Handbook includes specifications related to maintenance access. In addition, the Appendix to the LIDA Handbook includes a detailed maintenance checklist for each LIDA facility type, including infiltration planters as proposed and reflected in the preliminary design of the regional stormwater facilities in this Plan.

7.3 Next Steps

The focus of this Plan is to document the technical analyses used to develop sizes and costs of the RSFs for the North Bethany plan area.

The technical analyses were focused on facility selection, facility locations, design assumptions, sizing of the facilities, and estimating costs. To remain consistent with Washington County Ordinance 739 and the DMP, additional issues will need to be addressed as facilities approach final design. These issues include funding, land acquisition, development of the trail system, density changes, Washington County's layout of the road system, updates to the D&C Standards, Federal Emergency Management Agency and Endangered Species Act issues, and delineations of wetlands and vegetated corridor boundaries (the current mapped boundaries are approximate).

Section 8

Limitations

This document was prepared solely for Clean Water Services in accordance with professional standards at the time the services were performed and in accordance with the contract between Clean Water Services and Brown and Caldwell dated October 10, 2012. This document is governed by the specific scope of work authorized by Clean Water Services; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Clean Water Services and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Section 9

References

Akan, A. O. 1993. Urban Stormwater Hydrology, A Guide to Engineering Calculations. CRC Press: Boca Raton, Fla. pp. 101–102.

Brown and Caldwell. North Bethany Stormwater Implementation Plan. August 2012.

Chow, V.T.; D.R. Maidment and L.W. Mays. 1988. Applied Hydrology. San Francisco: McGraw-Hill, Inc. pp. 245–250.

Clean Water Services, Design and Construction Standards, Chapters 4 and 5. 2007.

Clean Water Services, Low Impact Development Approaches Handbook. July 2009.

Otak. December 2010. North Bethany Subarea Drainage Master Plan. Prepared for Washington County by Otak, Inc., 17355 SW Boones Ferry Road, Lake Oswego, OR 97035 (Project 13035).

Stubchaer, J.M. 1975. The Santa Barbara Urban Hydrology Method. Proceedings, National Symposium on Urban Hydrology and Sediment Control, University of Kentucky, Lexington, Kentucky. July 28–31,

United States Department of Agriculture (USDA). 1964 revised 1972 amend 1985. National Engineering Handbook Section 4 Hydrology, Chapter 10 Estimation of Direct Runoff from Storm Rainfall by Victor Mockus. Pg. 10.4, 10.5, 10.6a.

United States Department of Agriculture (USDA) Natural Resources Conservation Center (NRCS). 1982. Soil Survey of Washington County, Oregon.

United States Department of Agriculture (USDA) Natural Resources Conservation Center (NRCS). 1986. Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55).

United States Department of Agriculture (USDA) Natural Resources Conservation Center (NRCS). February 1992. Computer Program for Project Formulation Hydrology, Technical Release 20 (TR-20), Appendix G, Page G-12.

United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). September 1997. National Engineering Handbook, Part 630, Hydrology. U.S. Government Printing Office, Washington, D.C.

Washington County. North Bethany Land Use Ordinances: http://www.co.washington.or.us/LUT/PlanningProjects/Bethany/#AnchorA712

Appendix A: Maps

Appendix A-1: Plan Area and Vicinity Map

Appendix A-2: Proposed Land Use and LIDA Requirements

Appendix A-3: Subbasin Delineations for Regional Facilities

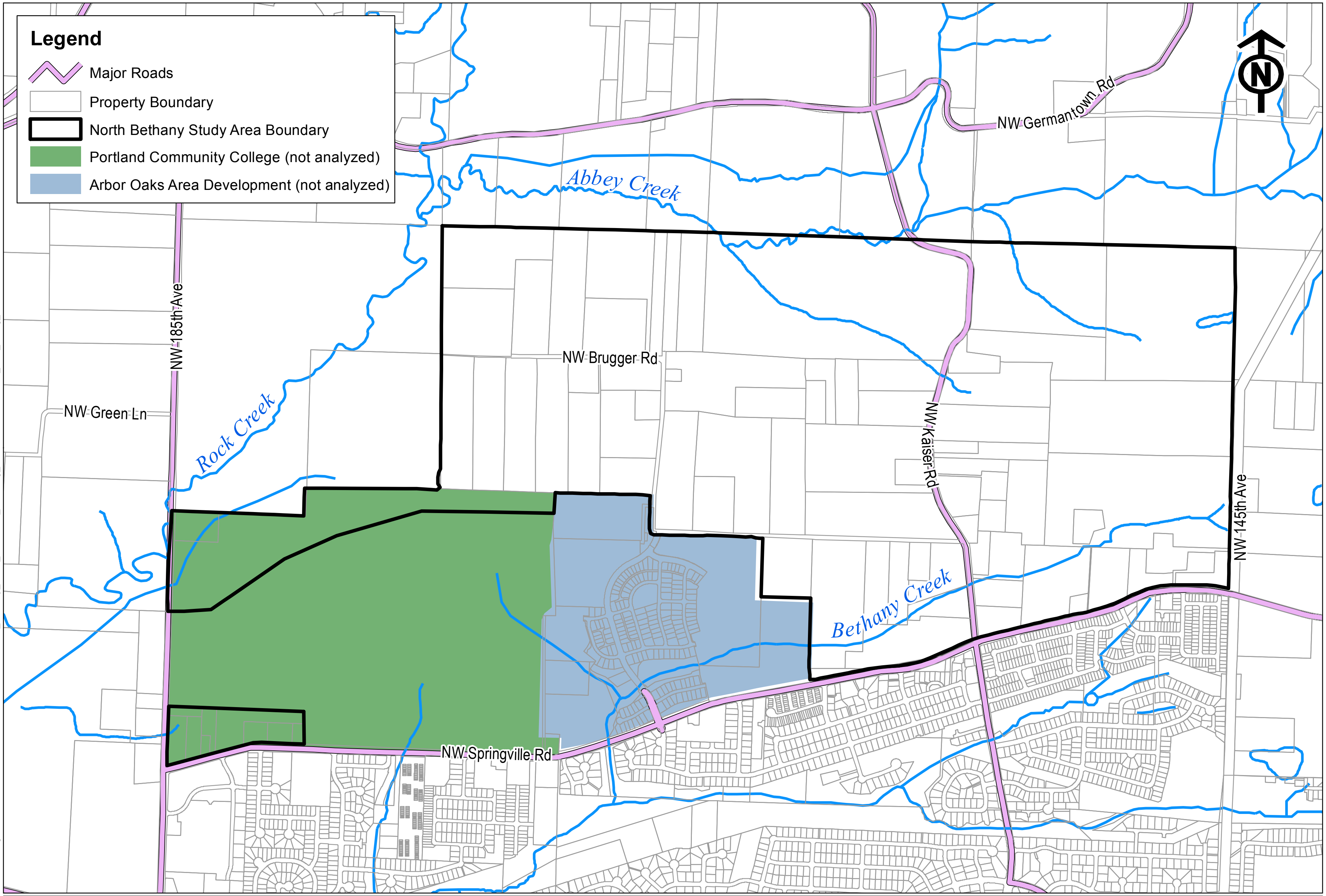
Appendix A-4: NRCS Hydrologic Soil Groups

Appendix A-5: 2010 Aerial Photography True Color

Appendix A-6: 2010 Aerial Photography Near-Infrared

Appendix A-7: Pre-developed Land Cover Mapping

Appendix A-8: Conveyance System Layout



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0.125 0 0.125 Mi

1 inch = 0.25 miles

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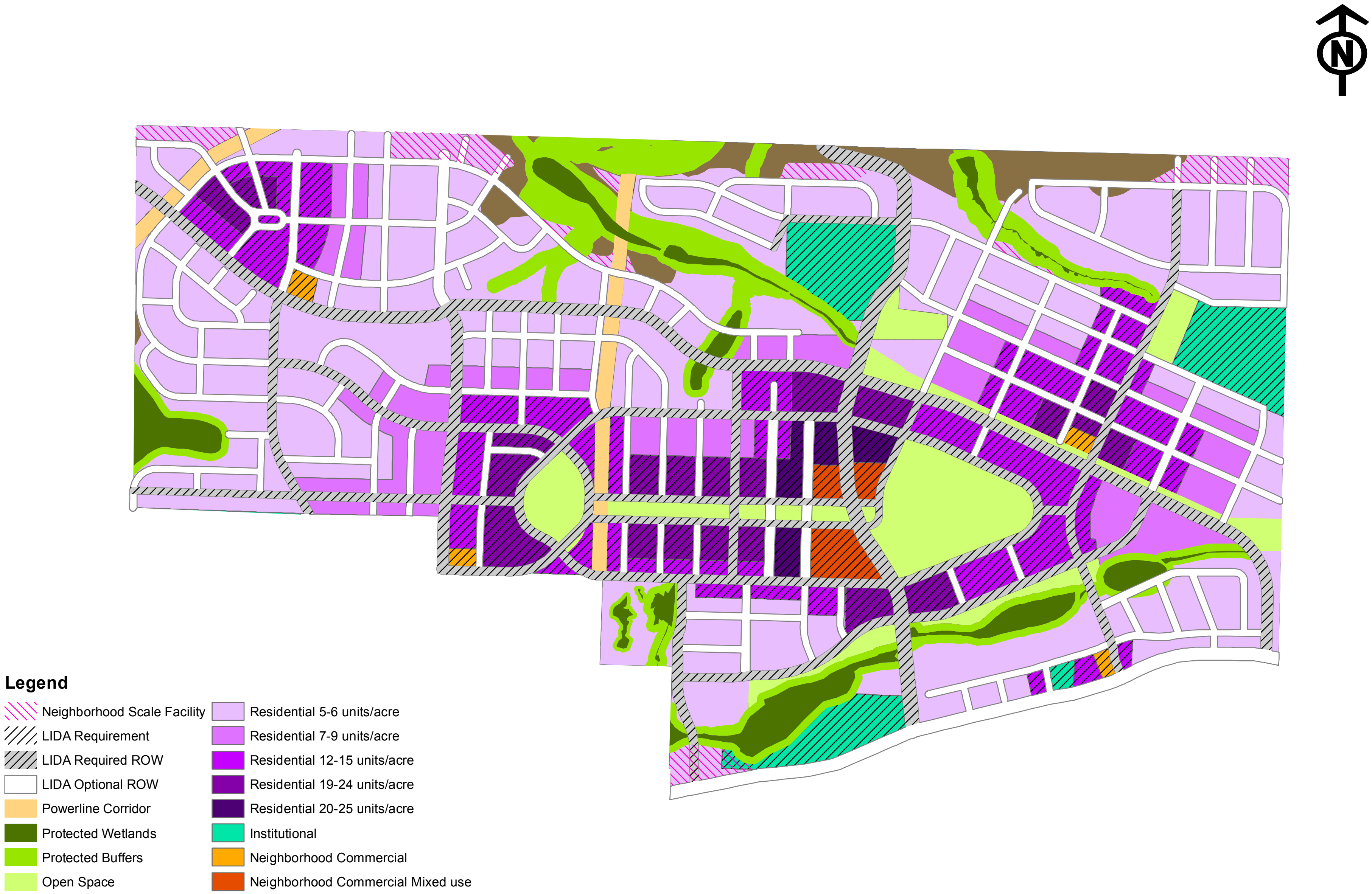
APPENDIX A-1

STUDY AREA AND VICINITY

North Bethany Stormwater Implementation Plan
SBUH Analysis for Regional Stormwater Facility Sizing and Costing



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1 inch = 1,000 feet

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APPENDIX A-2

PROPOSED LAND USE AND LIDA REQUIREMENTS

North Bethany Stormwater Implementation Plan
SBUH Analysis for Regional Stormwater Facility Sizing and Costing

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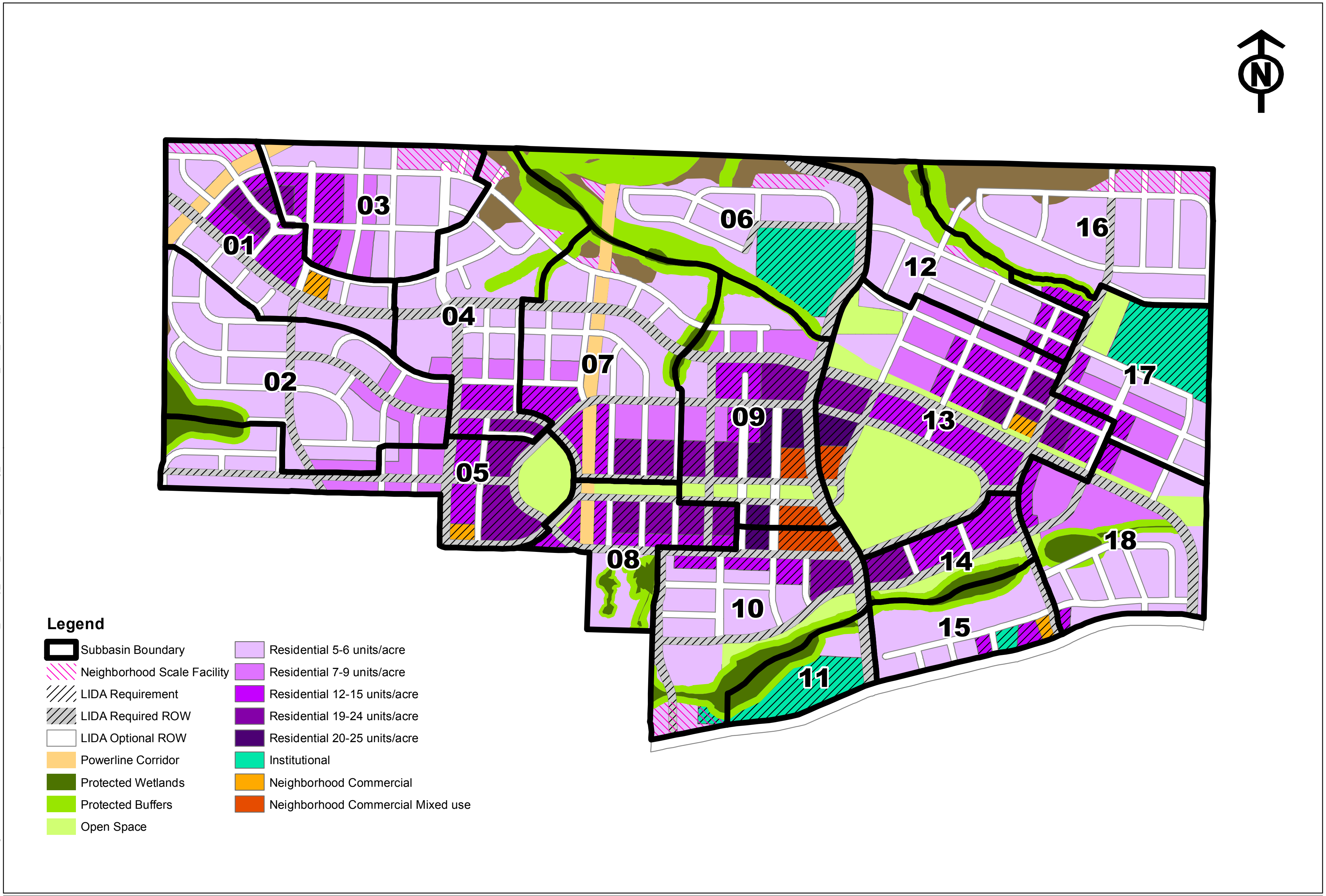

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1 inch = 1,000 feet

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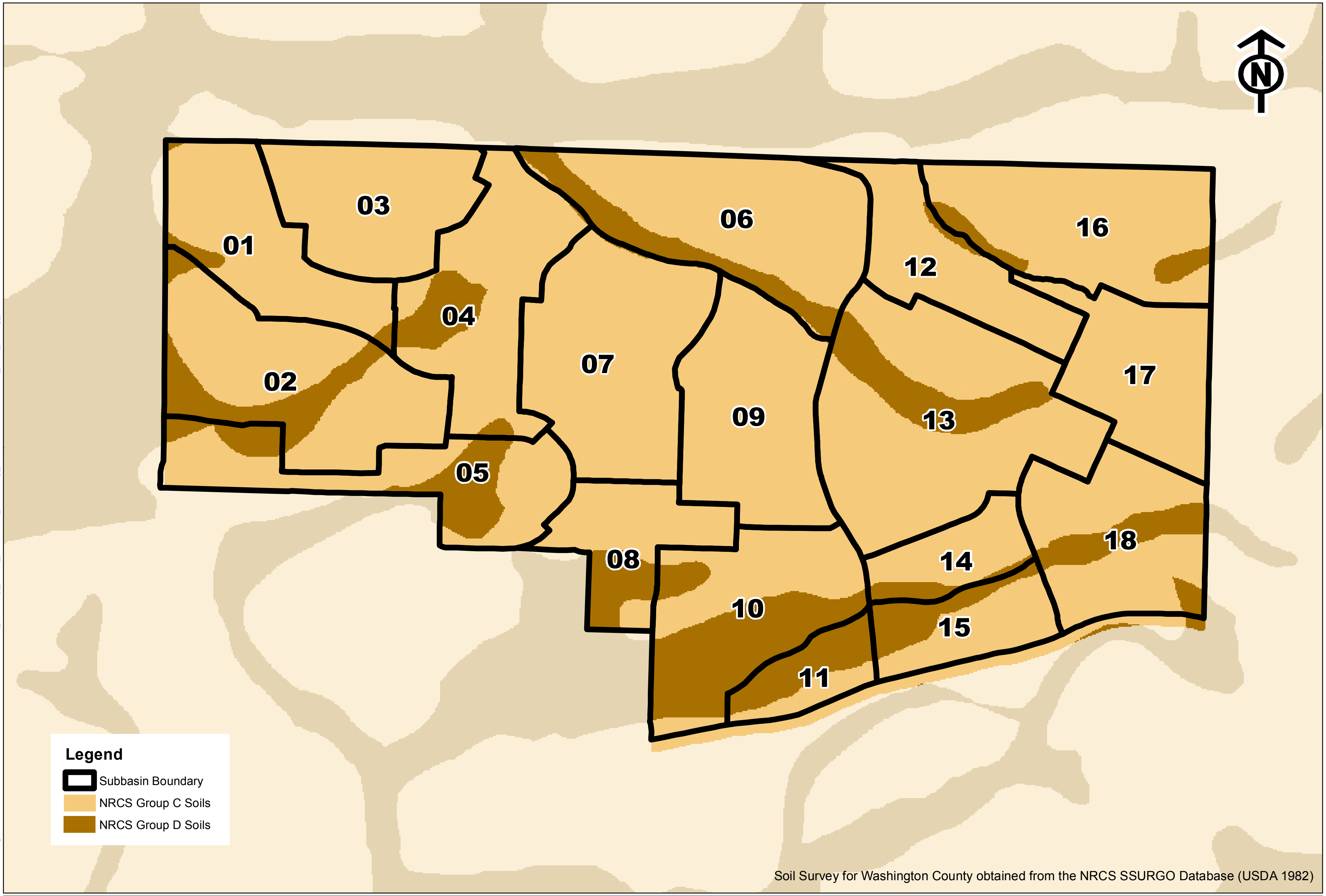
APPENDIX A-3

SUBBASIN DELINEATIONS FOR REGIONAL FACILITIES

North Bethany Stormwater Implementation Plan
SBUH Analysis for Regional Stormwater Facility Sizing and Costing



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Author: NFoged

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APPENDIX A-4

NRCS HYDROLOGIC SOIL GROUPS

North Bethany Stormwater Implementation Plan
SBUH Analysis for Regional Stormwater Facility Sizing and Costing

10/8/2013

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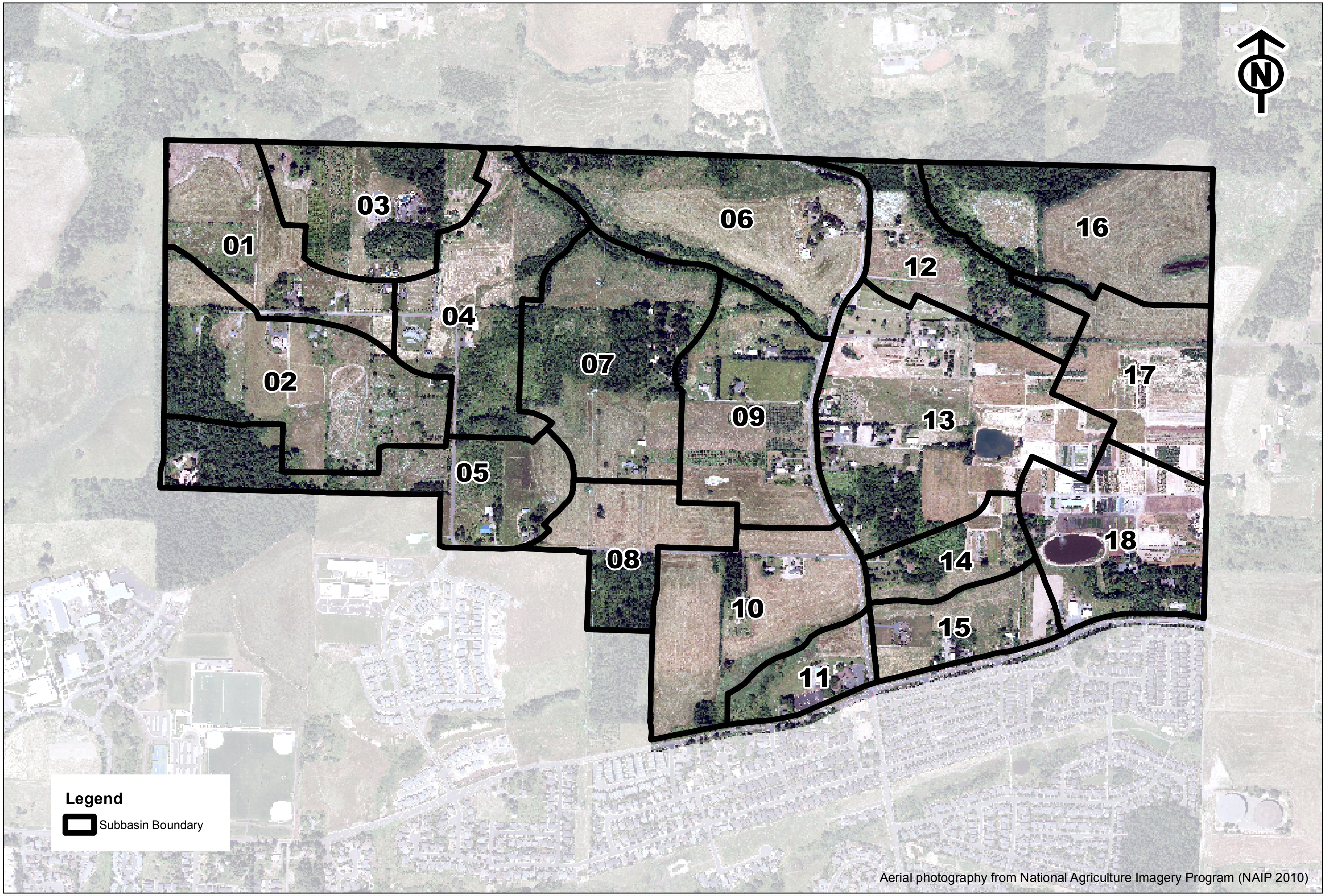
Author: NFoged



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500 0 500 FT

1 inch = 1,000 feet

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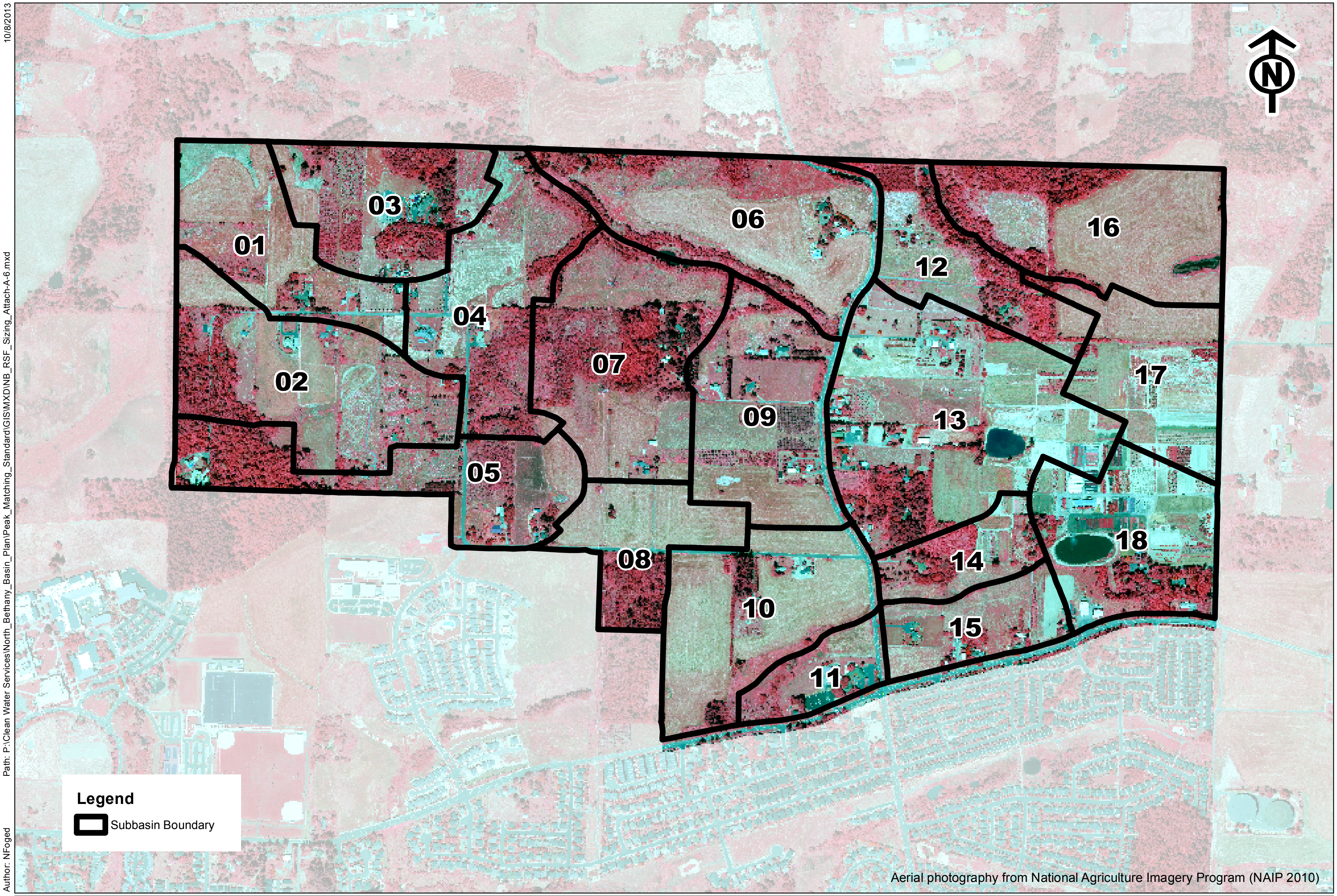
APPENDIX A-5

2010 AERIAL PHOTOGRAPHY TRUE COLOR

North Bethany Stormwater Implementation Plan
SBUH Analysis for Regional Stormwater Facility Sizing and Costing



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500 0 500 FT

1 inch = 1,000 feet

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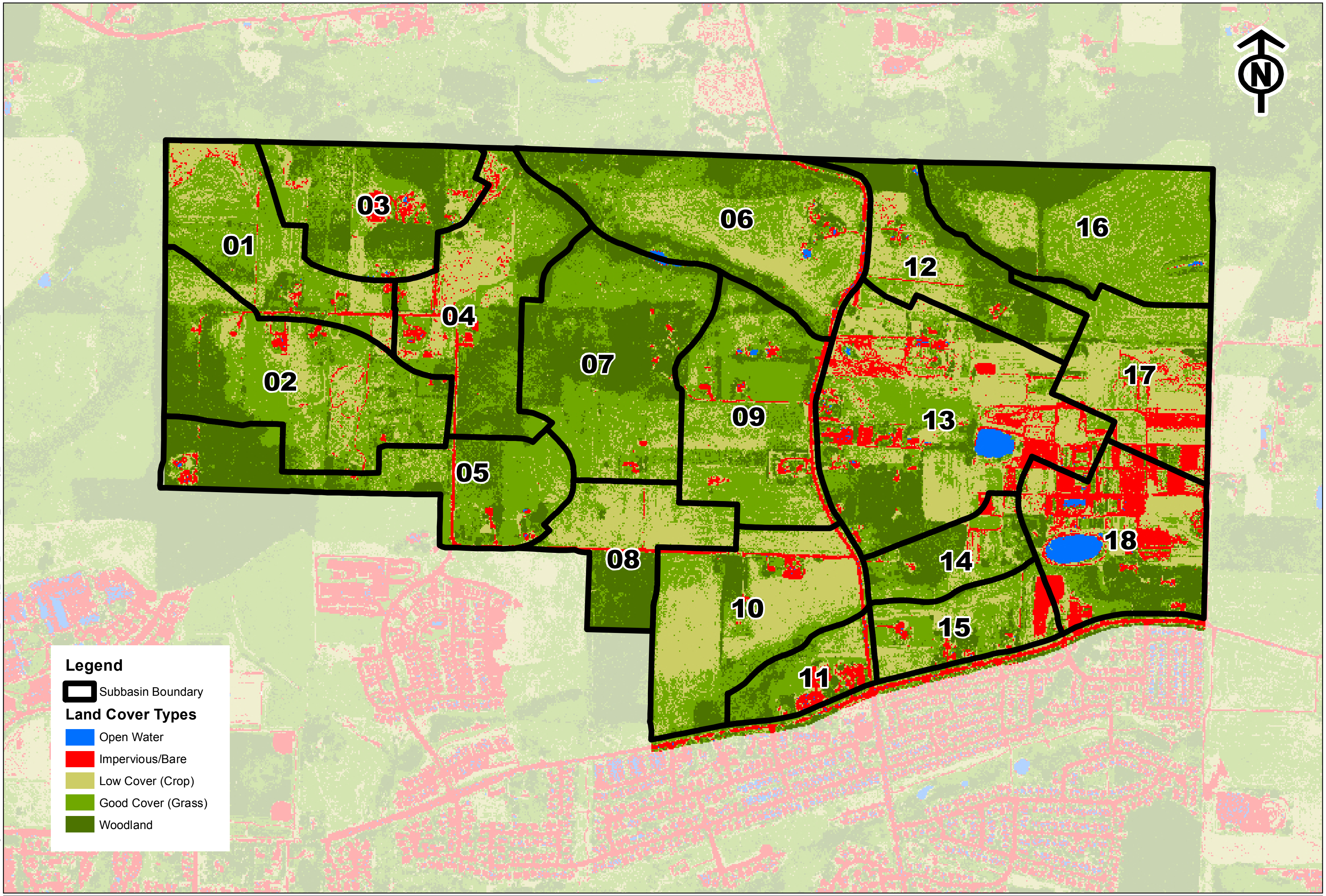
APPENDIX A-6

2010 AERIAL PHOTOGRAPHY NEAR-INFRARED

North Bethany Stormwater Implementation Plan
SBUH Analysis for Regional Stormwater Facility Sizing and Costing



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APPENDIX A-7

PRE-DEVELOPED LAND COVER MAPPING

North Bethany Stormwater Implementation Plan
SBUH Analysis for Regional Stormwater Facility Sizing and Costing

10/8/2013

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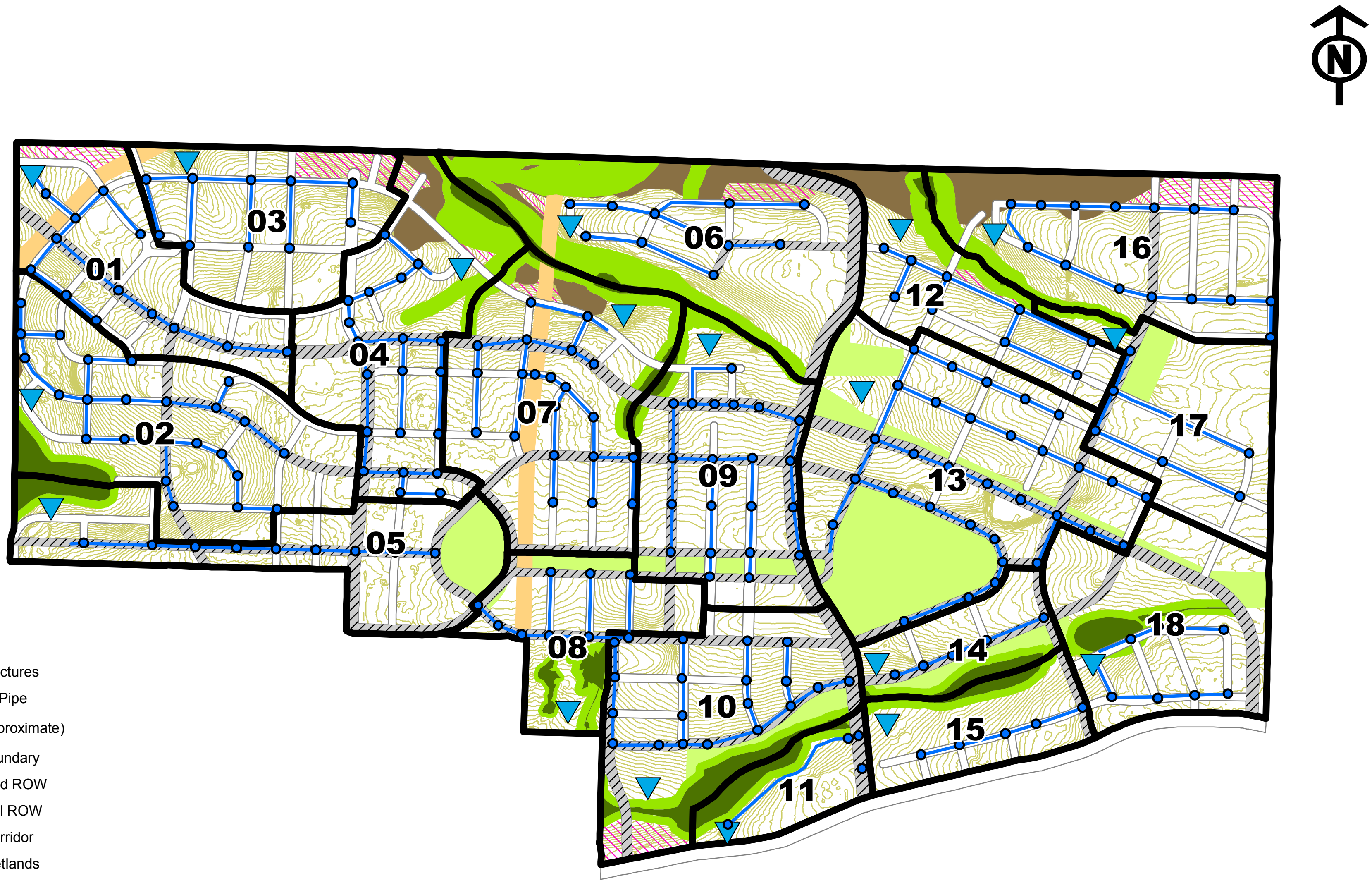

Legend

- Manhole Structures
- Conveyance Pipe
- RSF Site (approximate)
- Subbasin Boundary
- LIDA Required ROW
- LIDA Optional ROW
- Powerline Corridor
- Protected Wetlands
- Protected Buffers
- Open Space
- Neighborhood Scale Facility
- 2-foot Contour

500 0 500 FT

1 inch = 1,000 feet

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APPENDIX A-8

PRELIMINARY CONVEYANCE SYSTEM LAYOUT

North Bethany Stormwater Implementation Plan
SBUH Analysis for Regional Stormwater
Facility Sizing and Costing

Appendix B: Results Tables

Table B-1. Subbasin Areas and Imperviousness

Subbasin	Pre-developed areas (acres)					Post-developed areas (acres)					
	Contributing[a]			Non-contributing[b]	Total[e]	Contributing [a]				Non-contributing[b]	Total[e]
	Pervious	Impervious	Percent impervious			Pervious	Impervious with LIDA[c]	Impervious without LIDA[d]	Percent impervious		
01	27.5	1.3	4.5%	1.7	30.5	12.8	7.4	8.7	55.7%	1.7	30.5
02	42.6	1.3	2.9%	3.3	47.1	20.7	2.4	20.7	52.9%	3.3	47.1
03	26.4	1.7	6.1%	2.8	31.0	12.7	2.8	12.6	54.8%	2.8	31.0
04	28.1	2.3	7.4%	9.2	39.5	13.1	5.2	12.0	56.8%	9.2	39.5
05	30.8	1.4	4.4%	2.5	34.7	13.7	10.2	8.2	57.3%	2.5	34.7
06	28.6	1.3	4.2%	18.8	48.7	15.3	6.8	7.8	48.9%	18.8	48.7
07	40.7	0.3	0.8%	6.2	47.2	19.5	7.9	13.6	52.5%	6.2	47.2
08	17.7	0.5	2.6%	3.6	21.8	8.1	7.2	2.9	55.5%	3.6	21.8
09	34.7	2.1	5.7%	2.5	39.3	13.3	16.4	7.2	63.9%	2.5	39.3
10	29.5	1.8	5.7%	8.4	39.6	12.9	9.8	8.5	58.7%	8.4	39.6
11	6.3	1.9	23.5%	3.8	12.0	4.8	2.9	0.5	41.8%	3.8	12.0
12	18.5	0.5	2.7%	5.7	24.7	8.8	1.2	8.9	53.5%	5.7	24.7
13	55.7	10.4	15.8%	0.0	66.1	29.8	20.7	15.6	54.9%	0.0	66.1
14	10.6	0.7	5.8%	2.9	14.1	4.5	5.7	1.0	59.7%	2.9	14.1
15	12.9	1.8	12.4%	2.8	17.6	7.2	1.8	5.8	51.6%	2.8	17.6
16	28.8	0.0	0.1%	13.4	42.3	13.7	0.7	14.5	52.7%	13.4	42.3
17	23.6	4.3	15.3%	0.8	28.7	14.4	6.0	7.4	48.2%	0.8	28.7
18	21.3	9.8	31.5%	3.8	35.0	14.5	3.9	12.7	53.4%	3.8	35.0
Total/Avg.:	**484.3**	**43.3**	**8.2%**	**92.3**	**619.9**	**239.7**	**119.1**	**168.8**	**54.6**	**92.3**	**619.9**

a. Contributing areas were based on the post-development land use mapping, and include all areas except for restricted building areas such as wetlands, buffers, powerlines, and forested areas.

b. Non-contributing areas were based on the post-development land use mapping, and include restricted building areas such as wetlands, buffers, powerlines, and forested areas.

c. Impervious areas with LIDA were estimated based on LIDA-required land uses and LIDA required rights-of-way as described in Section 2.1.

d. Impervious areas without LIDA include all other areas where LIDA is optional.

e. Total Bethany study area is approximately 674 acres. Exclusion of the Portland Community College and Arbor Oaks properties reduces the total area to approximately 620 acres as shown above.

Table B-2. Peak Discharges for Design Storm Events												
Subbasin	Peak discharges (cfs)											
	2-year, 24-hour				10-year, 24-hour				25-year, 24-hour			
	Pre-developed	Post-developed without LIDA[a]	Post-developed with LIDA[b]	Post-developed mitigated[c]	Pre-developed	Post-developed without LIDA[a]	Post-developed with LIDA[b]	Post-developed mitigated[c]	Pre-developed	Post-developed without LIDA[a]	Post-developed with LIDA[b]	Post-developed mitigated[c]
01	4.2	11.2	7.1	4.2	8.5	17.1	11.4	8.5	10.7	20.1	17.4	10.7
02	6.4	17.0	15.6	6.4	13.0	26.1	24.2	13.0	16.4	30.6	29.9	16.4
03	3.6	11.0	9.4	3.6	7.7	16.9	14.6	7.7	9.9	19.8	19.2	9.9
04	4.4	12.2	9.3	4.4	8.9	18.6	14.5	8.9	11.2	21.7	19.6	11.2
05	3.6	12.0	6.5	3.6	7.8	18.2	12.0	7.8	10.1	21.3	18.5	10.1
06	5.1	10.9	7.1	5.1	9.8	17.1	11.7	9.8	12.2	20.1	17.6	12.2
07	3.7	15.2	10.7	3.7	8.9	23.5	17.3	8.9	11.8	27.6	24.4	11.8
08	3.4	7.0	3.0	3.4	6.4	10.8	7.2	6.4	7.9	12.6	11.0	7.9
09	5.1	15.7	6.5	5.1	10.5	23.6	15.2	10.5	13.4	27.4	23.5	13.4
10	7.6	13.4	7.7	7.6	13.2	20.2	13.4	13.2	16.0	23.6	21.7	16.0
11	1.8	2.9	1.2	1.8	3.2	4.6	3.1	3.2	3.9	5.4	4.7	3.9
12	2.7	7.3	6.6	2.7	5.5	11.2	10.2	5.5	7.0	13.1	12.8	7.0
13	8.6	18.0	9.4	8.6	15.9	27.8	19.5	15.9	19.5	32.6	26.9	19.5
14	1.4	4.5	1.3	1.4	3.1	6.9	4.5	3.1	3.9	8.0	6.9	3.9
15	2.9	5.7	4.7	2.9	5.4	8.9	7.4	5.4	6.6	10.4	10.0	6.6
16	3.8	11.1	10.7	3.8	8.0	17.1	16.6	8.0	10.1	20.0	19.8	10.1
17	5.9	9.9	6.5	5.9	10.5	15.5	10.8	10.5	12.9	18.3	16.3	12.9
18	7.0	11.6	9.4	7.0	12.2	17.9	14.9	12.2	14.9	21.0	18.9	14.9

a. Peak discharge calculated prior to adjustment for LIDA facilities as described in Section 3.4.

b. Peak discharge calculated after adjustment for LIDA facilities; runoff for LIDA-required areas routed through infiltration planter as described in Section 3.4.

c. Mitigated peak discharges match the pre-developed discharges in all cases because facilities sizes were adjusted to achieve peak matching; however, the final sizing was based on the 25-year event only.

Table B-3. RSF Sizing Results

Subbasin	Overflow outlet calculated minimum length[b] (ft)	Size requirements[a]									
		Water quality storm[c]			Peak storage[d] (25-year water surface)			Top of facility[e] (includes freeboard)			
		Depth (ft)	Surface area (ac)	Volume (ac-ft)	Depth (ft)	Surface area (ac)	Volume (ac-ft)	Depth (ft)	Surface area[f] (ac)	Volume[g] (ac-ft)	Sizing factor[h] (%)
01	9.45	1.06	0.48	0.48	3.00	0.56	1.49	4.00	0.60	2.08	3.8%
02	14.47	0.75	0.96	0.70	3.00	1.09	3.00	4.00	1.15	4.14	5.0%
03	8.70	0.82	0.59	0.46	3.00	0.68	1.84	4.00	0.73	2.56	4.8%
04	9.87	0.89	0.60	0.52	3.00	0.70	1.89	4.00	0.75	2.62	4.4%
05	8.88	1.06	0.55	0.55	3.00	0.63	1.70	4.00	0.68	2.36	3.7%
06	10.76	1.04	0.44	0.44	3.00	0.52	1.38	4.00	0.56	1.93	3.9%
07	10.36	0.85	0.78	0.65	3.00	0.90	2.44	4.00	0.95	3.38	4.4%
08	7.00	1.60	0.21	0.30	3.00	0.25	0.62	4.00	0.28	0.88	2.8%
09	11.77	1.36	0.55	0.71	3.00	0.62	1.66	4.00	0.67	2.31	2.8%
10	14.12	1.26	0.46	0.55	3.00	0.53	1.41	4.00	0.58	1.97	3.1%
11	3.47	1.87	0.07	0.10	3.00	0.09	0.19	4.00	0.10	0.28	3.0%
12	6.17	0.82	0.39	0.30	3.00	0.47	1.23	4.00	0.51	1.72	5.0%
13	17.21	1.09	1.03	1.09	3.00	1.14	3.15	4.00	1.21	4.34	3.3%
14	3.48	1.87	0.13	0.20	3.00	0.15	0.36	4.00	0.17	0.52	2.6%
15	5.85	0.97	0.25	0.23	3.00	0.31	0.80	4.00	0.35	1.13	4.5%
16	8.93	0.73	0.65	0.46	3.00	0.76	2.05	4.00	0.81	2.85	5.3%
17	11.34	1.16	0.37	0.40	3.00	0.43	1.13	4.00	0.47	1.59	3.5%
18	13.10	0.98	0.53	0.50	3.00	0.62	1.66	4.00	0.67	2.31	4.0%

a. Low-level outlet sizing not listed because all facilities assumed to have a 2-inch minimum orifice diameter except for Subbasin 18, which requires a 2.5-inch orifice diameter.

b. Overflow outlet lengths were adjusted such that the 25-year peak water surface elevation is passed with 0.5 foot of hydraulic head; overflow elevation at 2.5 feet for all facilities.

c. Water quality volume based on water quality rainfall depth of 0.36 inch as described in Section 2.2.1.

d. Peak storage calculations are based on the 25-year design storm event; this corresponds to a facility depth of 3 feet for all facilities.

e. The top of the regional stormwater facility corresponds to a 4-foot depth for all facilities; this includes 1 foot of freeboard above the 25-year peak water surface elevation.

f. Surface area associated with the internal storage volume at 4-foot depth. This does not include areas for berm or grading.

g. Storage volume within the facility at the 4-foot depth; total required storage volume for the facility (including freeboard).

h. Sizing factor calculated by dividing the facility surface area at the top of the facility (4-foot depth) by the total impervious area of the contributing drainage.

Table B-4. Unit Costs for Estimating RSF Costs		
Item	Unit	Unit cost, 2012 dollars
General earthwork/excavation	CY	12
Embankment	CY	8
Amended soils and mulch	CY	26
Water quality facility plantings	SF	3
Non-water quality facility landscaping	AC	20,600
Jute matting, biodegradable	SY	2
4-foot chain link fence and signage	LF	21
12-foot access road	SF	5
Energy dissipation pad: riprap, Class 50	CY	60
Rock weir: riprap, Class 50	CY	60
Outflow control structure	EA	5,100
Precast concrete manhole (48", 0'–8' deep)	EA	2,700
Precast concrete manhole (60", 0'–8' deep)	EA	4,200
WQ precast concrete manhole (60", 0'–8' deep)	EA	7,200
WQ precast concrete manhole (60", 9'–12' deep)	EA	11,000
WQ precast concrete manhole (60", 13'–20' deep)	EA	14,400
WQ precast concrete manhole (72", 0'–8' deep)	EA	8,500
WQ precast concrete manhole (72", 9'–12' deep)	EA	12,400
WQ precast concrete manhole (72", 13'–20' deep)	EA	15,500
Concrete inlet, Type G-2	EA	1,900
Mobilization/demobilization (10%)	LS	
Traffic control/utility relocation (2%)	LS	
Erosion control (2%)	LS	
Construction contingency (30%)	LS	
Permitting (5%)	LS	
Wetland mitigation	AC	175,000
Wetland delineation and permit	EA	10,000
Surveying and engineering (20%)	LS	
Construction engineering and administration (15%)	LS	

Table B-5. Pipe and Manhole Unit Costs			
Depth of cover, feet	Pipe diameter, inches		
	10–12	15–18	21–24
	2012 dollars per lineal foot		
2–5	49	73	97
5–10	63	93	122
10–15	78	113	148
15–20	93	133	173
Manhole, standard	$3,500		
Manhole, deep	$6,500		

Table B-6. RSF Detailed Costs

Subbasin	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	Total[b]
Footprint at max depth, SF	26,303	50,236	31,953	32,708	29,681	24,556	41,453	12,063	29,098	25,048	4,524	22,162	52,597	7,571	15,044	35,319	20,565	29,052	
Regional Stormwater Facility Costs (2012)																			
Earthwork and embankment	$64,200	$153,700	$105,300	$83,900	$72,400	$80,900	$130,000	$36,300	$95,900	$35,400	$6,500	$78,300	$46,900	$10,700	$21,400	$124,900	$67,700	$41,100	
Landscaping and planting (includes soil amendments)	$127,000	$231,100	$147,400	$148,400	$143,300	$113,300	$183,700	$58,400	$134,200	$144,700	$26,100	$95,300	$245,300	$43,700	$86,900	$151,800	$94,900	$167,800	
Outlet structures and pipe appurtenances	$31,800	$55,900	$52,700	$47,200	$31,800	$52,700	$49,600	$46,600	$52,700	$34,000	$34,000	$28,700	$54,400	$34,000	$34,000	$28,700	$52,700	$34,000	
Additional construction elements[a]	$31,200	$61,700	$42,800	$39,100	$34,700	$34,600	$50,900	$19,800	$39,600	$30,000	$9,300	$28,300	$48,500	$12,400	$19,900	$42,800	$30,200	$34,000	
Subtotal	**$254,200**	**$502,400**	**$348,200**	**$318,600**	**$282,200**	**$281,500**	**$414,200**	**$161,100**	**$322,400**	**$244,100**	**$75,900**	**$230,600**	**$395,100**	**$100,800**	**$162,200**	**$348,200**	**$245,500**	**$276,900**	
Construction Contingency (30%)	$76,300	$150,700	$104,500	$95,600	$84,700	$84,500	$124,300	$48,300	$96,700	$73,200	$22,800	$69,200	$118,500	$30,200	$48,700	$104,500	$73,700	$83,100	
Capital expense total	**$330,500**	**$653,100**	**$452,700**	**$414,200**	**$366,900**	**$366,000**	**$538,500**	**$209,400**	**$419,100**	**$317,300**	**$98,700**	**$299,800**	**$513,600**	**$131,000**	**$210,900**	**$452,700**	**$319,200**	**$360,000**	**$6,453,600**
Permitting (5%)	$16,500	$32,700	$22,600	$20,700	$18,300	$18,300	$26,900	$10,500	$21,000	$15,900	$4,900	$15,000	$25,700	$6,600	$10,500	$22,600	$16,000	$18,000	
Surveying and engineering (20%)	$66,100	$130,600	$90,500	$82,800	$73,400	$73,200	$107,700	$41,900	$83,800	$63,500	$19,700	$60,000	$102,700	$26,200	$42,200	$90,500	$63,800	$72,000	
Construction engineering and admin (15%)	$49,600	$98,000	$67,900	$62,200	$55,000	$54,900	$80,700	$31,500	$63,000	$47,700	$14,900	$45,000	$77,100	$19,800	$31,500	$67,900	$47,900	$54,100	
Administrative expense total	**$132,200**	**$261,300**	**$181,000**	**$165,700**	**$146,700**	**$146,400**	**$215,300**	**$83,900**	**$167,800**	**$127,100**	**$39,500**	**$120,000**	**$205,500**	**$52,600**	**$84,200**	**$181,000**	**$127,700**	**$144,100**	**$2,582,000**
Wetland mitigation and permitting													***						
Total construction cost, excluding land acquisition	**$462,700**	**$914,400**	**$633,700**	**$579,900**	**$513,600**	**$512,400**	**$753,800**	**$293,300**	**$586,900**	**$444,400**	**$138,200**	**$419,800**	**$719,100**	**$183,600**	**$295,100**	**$633,700**	**$446,900**	**$504,100**	**$9,035,600**

a. Includes mobilization, demobilization, traffic control, and erosion control.

b. Land acquisition costs, including appraisals, easements, and admin are not included in the above costs.

c. Wetland mitigation and permitting will be required for this subbasin Estimated costs for these efforts is $56,000 which is not included in the Total Construction Cost.

Table B-7. Conveyance System Detailed Costs

Subbasin	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	Total[a]
Material cost (see detail in separate table)	233,000	378,000	240,000	329,000	212,000	219,000	459,000	139,000	407,000	279,000	31,000	172,000	538,000	68,000	69,000	297,000	162,000	115,000	
Mobilization (10%)	23,000	38,000	24,000	33,000	21,000	22,000	46,000	14,000	41,000	28,000	3,000	17,000	54,000	7,000	7,000	30,000	16,000	12,000	
Traffic control (2%)	5,000	8,000	5,000	7,000	4,000	4,000	9,000	3,000	8,000	6,000	1,000	3,000	11,000	1,000	1,000	6,000	3,000	2,000	
Erosion and sediment control (2%)	4,660	7,560	4,800	6,580	4,240	4,380	9,180	2,780	8,140	5,580	620	3,440	10,760	1,360	1,380	5,940	3,240	2,300	
Construction contingency (30% on all above items)	80,000	129,000	82,000	113,000	72,000	75,000	157,000	48,000	139,000	96,000	11,000	59,000	184,000	23,000	24,000	102,000	55,000	39,000	
Capital expense total	**346,000**	**561,000**	**356,000**	**489,000**	**313,000**	**324,000**	**680,000**	**207,000**	**603,000**	**415,000**	**47,000**	**254,000**	**798,000**	**100,000**	**102,000**	**441,000**	**239,000**	**170,000**	**6,445,000**
Permitting (5%)	17,000	28,000	18,000	24,000	16,000	16,000	34,000	10,000	30,000	21,000	2,000	13,000	40,000	5,000	5,000	22,000	12,000	9,000	
Surveying and engineering (20%)	69,000	112,000	71,000	98,000	63,000	65,000	136,000	41,000	121,000	83,000	9,000	51,000	160,000	20,000	20,000	88,000	48,000	34,000	
Construction engineering and admin (15%)	52,000	84,000	53,000	73,000	47,000	49,000	102,000	31,000	90,000	62,000	7,000	38,000	120,000	15,000	15,000	66,000	36,000	26,000	
Administrative expense total	138,000	224,000	142,000	195,000	126,000	130,000	272,000	82,000	241,000	166,000	18,000	102,000	320,000	40,000	40,000	176,000	96,000	69,000	**2,577,000**
Total construction cost, excluding land acquisition	**$484,000**	**$785,000**	**$498,000**	**$684,000**	**$439,000**	**$454,000**	**$952,000**	**$289,000**	**$844,000**	**$581,000**	**$65,000**	**$356,000**	**$1,118,000**	**$140,000**	**$142,000**	**$617,000**	**$335,000**	**$239,000**	**$9,022,000**

a. Land acquisition costs, including appraisals, easements, and admin are not included in the above costs.

Note: The above costs are for the main trunkline system only (i.e., mainline pipes and manholes). Catch basins, curb inlets, field inlets, laterals, and other miscellaneous structures are not included.

Appendix C: Rainfall Distribution

NRCS Type 1A in 6-minute increments from TR-20 (USDA, 1992)

Table C-1. NRCS Type 1A Rainfall Distribution								
Time (hour)	Cumulative rainfall	Incremental rainfall	Incremental rainfall depth (inches)					
			2-year	5-year	10-year	25-year	50-year	100-year
			2.50	3.10	3.45	3.90	4.20	4.50
0.0	0.00%	0.00%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.1	0.22%	0.22%	0.0055	0.0068	0.0076	0.0086	0.0092	0.0099
0.2	0.43%	0.21%	0.0053	0.0065	0.0072	0.0082	0.0088	0.0095
0.3	0.63%	0.20%	0.0050	0.0062	0.0069	0.0078	0.0084	0.0090
0.4	0.82%	0.19%	0.0048	0.0059	0.0066	0.0074	0.0080	0.0086
0.5	1.00%	0.18%	0.0045	0.0056	0.0062	0.0070	0.0076	0.0081
0.6	1.18%	0.18%	0.0045	0.0056	0.0062	0.0070	0.0076	0.0081
0.7	1.37%	0.19%	0.0048	0.0059	0.0066	0.0074	0.0080	0.0086
0.8	1.57%	0.20%	0.0050	0.0062	0.0069	0.0078	0.0084	0.0090
0.9	1.78%	0.21%	0.0053	0.0065	0.0072	0.0082	0.0088	0.0095
1.0	2.00%	0.22%	0.0055	0.0068	0.0076	0.0086	0.0092	0.0099
1.1	2.28%	0.28%	0.0070	0.0087	0.0097	0.0109	0.0118	0.0126
1.2	2.57%	0.29%	0.0073	0.0090	0.0100	0.0113	0.0122	0.0131
1.3	2.87%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
1.4	3.18%	0.31%	0.0078	0.0096	0.0107	0.0121	0.0130	0.0140
1.5	3.50%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
1.6	3.80%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
1.7	4.10%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
1.8	4.39%	0.29%	0.0073	0.0090	0.0100	0.0113	0.0122	0.0131
1.9	4.70%	0.31%	0.0078	0.0096	0.0107	0.0121	0.0130	0.0140
2.0	5.00%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
2.1	5.31%	0.31%	0.0078	0.0096	0.0107	0.0121	0.0130	0.0140
2.2	5.63%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
2.3	5.95%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
2.4	6.28%	0.33%	0.0082	0.0102	0.0114	0.0129	0.0139	0.0149
2.5	6.60%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
2.6	6.92%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
2.7	7.24%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
2.8	7.56%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
2.9	7.88%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
3.0	8.20%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
3.1	8.51%	0.31%	0.0077	0.0096	0.0107	0.0121	0.0130	0.0140
3.2	8.83%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
3.3	9.15%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
3.4	9.47%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
3.5	9.80%	0.33%	0.0082	0.0102	0.0114	0.0129	0.0139	0.0149
3.6	10.15%	0.35%	0.0088	0.0109	0.0121	0.0137	0.0147	0.0158

Table C-1. NRCS Type 1A Rainfall Distribution								
Time (hour)	Cumulative rainfall	Incremental rainfall	Incremental rainfall depth (inches)					
			2-year	5-year	10-year	25-year	50-year	100-year
			2.50	3.10	3.45	3.90	4.20	4.50
3.7	10.50%	0.35%	0.0087	0.0109	0.0121	0.0137	0.0147	0.0158
3.8	10.86%	0.36%	0.0090	0.0112	0.0124	0.0140	0.0151	0.0162
3.9	11.23%	0.37%	0.0092	0.0115	0.0128	0.0144	0.0155	0.0167
4.0	11.60%	0.37%	0.0093	0.0115	0.0128	0.0144	0.0155	0.0167
4.1	11.97%	0.37%	0.0092	0.0115	0.0128	0.0144	0.0155	0.0167
4.2	12.34%	0.37%	0.0092	0.0115	0.0128	0.0144	0.0155	0.0167
4.3	12.72%	0.38%	0.0095	0.0118	0.0131	0.0148	0.0160	0.0171
4.4	13.11%	0.39%	0.0097	0.0121	0.0135	0.0152	0.0164	0.0175
4.5	13.50%	0.39%	0.0098	0.0121	0.0135	0.0152	0.0164	0.0176
4.6	13.90%	0.40%	0.0100	0.0124	0.0138	0.0156	0.0168	0.0180
4.7	14.31%	0.41%	0.0103	0.0127	0.0141	0.0160	0.0172	0.0185
4.8	14.73%	0.42%	0.0105	0.0130	0.0145	0.0164	0.0176	0.0189
4.9	15.16%	0.43%	0.0108	0.0133	0.0148	0.0168	0.0181	0.0194
5.0	15.60%	0.44%	0.0110	0.0136	0.0152	0.0172	0.0185	0.0198
5.1	16.06%	0.46%	0.0115	0.0143	0.0159	0.0179	0.0193	0.0207
5.2	16.53%	0.47%	0.0118	0.0146	0.0162	0.0183	0.0197	0.0212
5.3	17.01%	0.48%	0.0120	0.0149	0.0166	0.0187	0.0202	0.0216
5.4	17.50%	0.49%	0.0123	0.0152	0.0169	0.0191	0.0206	0.0220
5.5	18.00%	0.50%	0.0125	0.0155	0.0173	0.0195	0.0210	0.0225
5.6	18.49%	0.49%	0.0123	0.0152	0.0169	0.0191	0.0206	0.0221
5.7	19.00%	0.51%	0.0128	0.0158	0.0176	0.0199	0.0214	0.0230
5.8	19.52%	0.52%	0.0130	0.0161	0.0179	0.0203	0.0218	0.0234
5.9	20.05%	0.53%	0.0133	0.0164	0.0183	0.0207	0.0223	0.0239
6.0	20.60%	0.55%	0.0137	0.0170	0.0190	0.0214	0.0231	0.0247
6.1	21.20%	0.60%	0.0150	0.0186	0.0207	0.0234	0.0252	0.0270
6.2	21.81%	0.61%	0.0153	0.0189	0.0210	0.0238	0.0256	0.0275
6.3	22.43%	0.62%	0.0155	0.0192	0.0214	0.0242	0.0260	0.0279
6.4	23.06%	0.63%	0.0158	0.0195	0.0217	0.0246	0.0265	0.0284
6.5	23.70%	0.64%	0.0160	0.0198	0.0221	0.0250	0.0269	0.0288
6.6	24.29%	0.59%	0.0148	0.0183	0.0204	0.0230	0.0248	0.0266
6.7	24.88%	0.59%	0.0148	0.0183	0.0204	0.0230	0.0248	0.0265
6.8	25.49%	0.61%	0.0153	0.0189	0.0210	0.0238	0.0256	0.0275
6.9	26.13%	0.64%	0.0160	0.0198	0.0221	0.0250	0.0269	0.0288
7.0	26.80%	0.67%	0.0168	0.0208	0.0231	0.0261	0.0281	0.0302
7.1	27.52%	0.72%	0.0180	0.0223	0.0248	0.0281	0.0302	0.0324
7.2	28.29%	0.77%	0.0193	0.0239	0.0266	0.0300	0.0323	0.0346
7.3	29.12%	0.83%	0.0208	0.0257	0.0286	0.0324	0.0349	0.0374

Table C-1. NRCS Type 1A Rainfall Distribution								
Time (hour)	Cumulative rainfall	Incremental rainfall	Incremental rainfall depth (inches)					
			2-year	5-year	10-year	25-year	50-year	100-year
			2.50	3.10	3.45	3.90	4.20	4.50
7.4	30.02%	0.90%	0.0225	0.0279	0.0311	0.0351	0.0378	0.0405
7.5	31.00%	0.98%	0.0245	0.0304	0.0338	0.0382	0.0412	0.0441
7.6	33.14%	2.14%	0.0535	0.0663	0.0738	0.0835	0.0899	0.0963
7.7	35.47%	2.33%	0.0583	0.0722	0.0804	0.0909	0.0979	0.1049
7.8	37.88%	2.41%	0.0603	0.0747	0.0831	0.0940	0.1012	0.1085
7.9	40.26%	2.38%	0.0595	0.0738	0.0821	0.0928	0.1000	0.1071
8.0	42.50%	2.24%	0.0560	0.0694	0.0773	0.0874	0.0941	0.1008
8.1	43.94%	1.44%	0.0360	0.0446	0.0497	0.0562	0.0605	0.0648
8.2	45.17%	1.23%	0.0307	0.0381	0.0424	0.0480	0.0517	0.0553
8.3	46.23%	1.06%	0.0265	0.0329	0.0366	0.0413	0.0445	0.0477
8.4	47.16%	0.93%	0.0233	0.0288	0.0321	0.0363	0.0391	0.0419
8.5	48.00%	0.84%	0.0210	0.0260	0.0290	0.0328	0.0353	0.0378
8.6	48.90%	0.90%	0.0225	0.0279	0.0311	0.0351	0.0378	0.0405
8.7	49.75%	0.85%	0.0213	0.0264	0.0293	0.0332	0.0357	0.0383
8.8	50.55%	0.80%	0.0200	0.0248	0.0276	0.0312	0.0336	0.0360
8.9	51.30%	0.75%	0.0188	0.0233	0.0259	0.0293	0.0315	0.0338
9.0	52.00%	0.70%	0.0175	0.0217	0.0242	0.0273	0.0294	0.0315
9.1	52.66%	0.66%	0.0165	0.0205	0.0228	0.0257	0.0277	0.0297
9.2	53.29%	0.63%	0.0158	0.0195	0.0217	0.0246	0.0265	0.0284
9.3	53.89%	0.60%	0.0150	0.0186	0.0207	0.0234	0.0252	0.0270
9.4	54.46%	0.57%	0.0142	0.0177	0.0197	0.0222	0.0239	0.0256
9.5	55.00%	0.54%	0.0135	0.0167	0.0186	0.0211	0.0227	0.0243
9.6	55.56%	0.56%	0.0140	0.0174	0.0193	0.0218	0.0235	0.0252
9.7	56.12%	0.56%	0.0140	0.0174	0.0193	0.0218	0.0235	0.0252
9.8	56.66%	0.54%	0.0135	0.0167	0.0186	0.0211	0.0227	0.0243
9.9	57.18%	0.52%	0.0130	0.0161	0.0179	0.0203	0.0218	0.0234
10.0	57.70%	0.52%	0.0130	0.0161	0.0179	0.0203	0.0218	0.0234
10.1	58.20%	0.50%	0.0125	0.0155	0.0173	0.0195	0.0210	0.0225
10.2	58.68%	0.48%	0.0120	0.0149	0.0166	0.0187	0.0202	0.0216
10.3	59.16%	0.48%	0.0120	0.0149	0.0166	0.0187	0.0202	0.0216
10.4	59.64%	0.48%	0.0120	0.0149	0.0166	0.0187	0.0202	0.0216
10.5	60.10%	0.46%	0.0115	0.0143	0.0159	0.0179	0.0193	0.0207
10.6	60.58%	0.48%	0.0120	0.0149	0.0166	0.0187	0.0202	0.0216
10.7	61.04%	0.46%	0.0115	0.0143	0.0159	0.0179	0.0193	0.0207
10.8	61.50%	0.46%	0.0115	0.0143	0.0159	0.0179	0.0193	0.0207
10.9	61.96%	0.46%	0.0115	0.0143	0.0159	0.0179	0.0193	0.0207
11.0	62.40%	0.44%	0.0110	0.0136	0.0152	0.0172	0.0185	0.0198

Table C-1. NRCS Type 1A Rainfall Distribution								
Time (hour)	Cumulative rainfall	Incremental rainfall	Incremental rainfall depth (inches)					
			2-year	5-year	10-year	25-year	50-year	100-year
			2.50	3.10	3.45	3.90	4.20	4.50
11.1	62.84%	0.44%	0.0110	0.0136	0.0152	0.0172	0.0185	0.0198
11.2	63.26%	0.42%	0.0105	0.0130	0.0145	0.0164	0.0176	0.0189
11.3	63.68%	0.42%	0.0105	0.0130	0.0145	0.0164	0.0176	0.0189
11.4	64.10%	0.42%	0.0105	0.0130	0.0145	0.0164	0.0176	0.0189
11.5	64.50%	0.40%	0.0100	0.0124	0.0138	0.0156	0.0168	0.0180
11.6	64.89%	0.39%	0.0098	0.0121	0.0135	0.0152	0.0164	0.0176
11.7	65.27%	0.38%	0.0095	0.0118	0.0131	0.0148	0.0160	0.0171
11.8	65.65%	0.38%	0.0095	0.0118	0.0131	0.0148	0.0160	0.0171
11.9	66.03%	0.38%	0.0095	0.0118	0.0131	0.0148	0.0160	0.0171
12.0	66.40%	0.37%	0.0093	0.0115	0.0128	0.0144	0.0155	0.0167
12.1	66.77%	0.37%	0.0092	0.0115	0.0128	0.0144	0.0155	0.0166
12.2	67.15%	0.38%	0.0095	0.0118	0.0131	0.0148	0.0160	0.0171
12.3	67.53%	0.38%	0.0095	0.0118	0.0131	0.0148	0.0160	0.0171
12.4	67.91%	0.38%	0.0095	0.0118	0.0131	0.0148	0.0160	0.0171
12.5	68.30%	0.39%	0.0098	0.0121	0.0135	0.0152	0.0164	0.0176
12.6	68.66%	0.36%	0.0090	0.0112	0.0124	0.0140	0.0151	0.0162
12.7	69.03%	0.37%	0.0093	0.0115	0.0128	0.0144	0.0155	0.0167
12.8	69.39%	0.36%	0.0090	0.0112	0.0124	0.0140	0.0151	0.0162
12.9	69.74%	0.35%	0.0088	0.0109	0.0121	0.0137	0.0147	0.0158
13.0	70.10%	0.36%	0.0090	0.0112	0.0124	0.0140	0.0151	0.0162
13.1	70.47%	0.37%	0.0093	0.0115	0.0128	0.0144	0.0155	0.0167
13.2	70.84%	0.37%	0.0093	0.0115	0.0128	0.0144	0.0155	0.0167
13.3	71.20%	0.36%	0.0090	0.0112	0.0124	0.0140	0.0151	0.0162
13.4	71.55%	0.35%	0.0088	0.0109	0.0121	0.0137	0.0147	0.0158
13.5	71.90%	0.35%	0.0087	0.0108	0.0121	0.0136	0.0147	0.0157
13.6	72.25%	0.35%	0.0088	0.0109	0.0121	0.0137	0.0147	0.0158
13.7	72.59%	0.34%	0.0085	0.0105	0.0117	0.0133	0.0143	0.0153
13.8	72.93%	0.34%	0.0085	0.0105	0.0117	0.0133	0.0143	0.0153
13.9	73.26%	0.33%	0.0083	0.0102	0.0114	0.0129	0.0139	0.0149
14.0	73.60%	0.34%	0.0085	0.0105	0.0117	0.0133	0.0143	0.0153
14.1	73.94%	0.34%	0.0085	0.0105	0.0117	0.0133	0.0143	0.0153
14.2	74.28%	0.34%	0.0085	0.0105	0.0117	0.0133	0.0143	0.0153
14.3	74.61%	0.33%	0.0082	0.0102	0.0114	0.0129	0.0139	0.0148
14.4	74.95%	0.34%	0.0085	0.0105	0.0117	0.0133	0.0143	0.0153
14.5	75.28%	0.33%	0.0082	0.0102	0.0114	0.0129	0.0139	0.0148
14.6	75.61%	0.33%	0.0082	0.0102	0.0114	0.0129	0.0139	0.0148
14.7	75.94%	0.33%	0.0082	0.0102	0.0114	0.0129	0.0139	0.0148

Table C-1. NRCS Type 1A Rainfall Distribution								
Time (hour)	Cumulative rainfall	Incremental rainfall	Incremental rainfall depth (inches)					
			2-year	5-year	10-year	25-year	50-year	100-year
			2.50	3.10	3.45	3.90	4.20	4.50
14.8	76.27%	0.33%	0.0083	0.0102	0.0114	0.0129	0.0139	0.0149
14.9	76.60%	0.33%	0.0082	0.0102	0.0114	0.0129	0.0139	0.0148
15.0	76.92%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
15.1	77.25%	0.33%	0.0082	0.0102	0.0114	0.0129	0.0139	0.0148
15.2	77.57%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
15.3	77.89%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
15.4	78.21%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
15.5	78.53%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
15.6	78.85%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
15.7	79.16%	0.31%	0.0077	0.0096	0.0107	0.0121	0.0130	0.0140
15.8	79.47%	0.31%	0.0077	0.0096	0.0107	0.0121	0.0130	0.0140
15.9	79.79%	0.32%	0.0080	0.0099	0.0110	0.0125	0.0134	0.0144
16.0	80.10%	0.31%	0.0077	0.0096	0.0107	0.0121	0.0130	0.0140
16.1	80.41%	0.31%	0.0077	0.0096	0.0107	0.0121	0.0130	0.0140
16.2	80.71%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
16.3	81.02%	0.31%	0.0077	0.0096	0.0107	0.0121	0.0130	0.0140
16.4	81.32%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
16.5	81.63%	0.31%	0.0077	0.0096	0.0107	0.0121	0.0130	0.0140
16.6	81.93%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
16.7	82.23%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
16.8	82.52%	0.29%	0.0073	0.0090	0.0100	0.0113	0.0122	0.0131
16.9	82.82%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
17.0	83.12%	0.30%	0.0075	0.0093	0.0104	0.0117	0.0126	0.0135
17.1	83.41%	0.29%	0.0072	0.0090	0.0100	0.0113	0.0122	0.0130
17.2	83.70%	0.29%	0.0073	0.0090	0.0100	0.0113	0.0122	0.0131
17.3	83.99%	0.29%	0.0073	0.0090	0.0100	0.0113	0.0122	0.0131
17.4	84.28%	0.29%	0.0073	0.0090	0.0100	0.0113	0.0122	0.0131
17.5	84.57%	0.29%	0.0073	0.0090	0.0100	0.0113	0.0122	0.0131
17.6	84.86%	0.29%	0.0073	0.0090	0.0100	0.0113	0.0122	0.0131
17.7	85.14%	0.28%	0.0070	0.0087	0.0097	0.0109	0.0118	0.0126
17.8	85.42%	0.28%	0.0070	0.0087	0.0097	0.0109	0.0118	0.0126
17.9	85.70%	0.28%	0.0070	0.0087	0.0097	0.0109	0.0118	0.0126
18.0	85.98%	0.28%	0.0070	0.0087	0.0097	0.0109	0.0118	0.0126
18.1	86.26%	0.28%	0.0070	0.0087	0.0097	0.0109	0.0118	0.0126
18.2	86.54%	0.28%	0.0070	0.0087	0.0097	0.0109	0.0118	0.0126
18.3	86.81%	0.27%	0.0068	0.0084	0.0093	0.0105	0.0113	0.0122
18.4	87.09%	0.28%	0.0070	0.0087	0.0097	0.0109	0.0118	0.0126

Table C-1. NRCS Type 1A Rainfall Distribution								
Time (hour)	Cumulative rainfall	Incremental rainfall	Incremental rainfall depth (inches)					
			2-year	5-year	10-year	25-year	50-year	100-year
			2.50	3.10	3.45	3.90	4.20	4.50
18.5	87.36%	0.27%	0.0068	0.0084	0.0093	0.0105	0.0113	0.0122
18.6	87.63%	0.27%	0.0067	0.0084	0.0093	0.0105	0.0113	0.0121
18.7	87.90%	0.27%	0.0068	0.0084	0.0093	0.0105	0.0113	0.0122
18.8	88.17%	0.27%	0.0068	0.0084	0.0093	0.0105	0.0113	0.0122
18.9	88.44%	0.27%	0.0067	0.0084	0.0093	0.0105	0.0113	0.0121
19.0	88.70%	0.26%	0.0065	0.0081	0.0090	0.0101	0.0109	0.0117
19.1	88.96%	0.26%	0.0065	0.0081	0.0090	0.0101	0.0109	0.0117
19.2	89.23%	0.27%	0.0068	0.0084	0.0093	0.0105	0.0113	0.0122
19.3	89.49%	0.26%	0.0065	0.0081	0.0090	0.0101	0.0109	0.0117
19.4	89.74%	0.25%	0.0062	0.0077	0.0086	0.0097	0.0105	0.0112
19.5	90.00%	0.26%	0.0065	0.0081	0.0090	0.0101	0.0109	0.0117
19.6	90.26%	0.26%	0.0065	0.0081	0.0090	0.0101	0.0109	0.0117
19.7	90.51%	0.25%	0.0063	0.0078	0.0086	0.0098	0.0105	0.0113
19.8	90.76%	0.25%	0.0062	0.0077	0.0086	0.0097	0.0105	0.0112
19.9	91.01%	0.25%	0.0063	0.0078	0.0086	0.0098	0.0105	0.0113
20.0	91.26%	0.25%	0.0062	0.0077	0.0086	0.0097	0.0105	0.0112
20.1	91.51%	0.25%	0.0063	0.0078	0.0086	0.0098	0.0105	0.0113
20.2	91.76%	0.25%	0.0062	0.0077	0.0086	0.0097	0.0105	0.0112
20.3	92.00%	0.24%	0.0060	0.0074	0.0083	0.0094	0.0101	0.0108
20.4	92.25%	0.25%	0.0062	0.0077	0.0086	0.0097	0.0105	0.0112
20.5	92.49%	0.24%	0.0060	0.0074	0.0083	0.0094	0.0101	0.0108
20.6	92.73%	0.24%	0.0060	0.0074	0.0083	0.0094	0.0101	0.0108
20.7	92.97%	0.24%	0.0060	0.0074	0.0083	0.0094	0.0101	0.0108
20.8	93.21%	0.24%	0.0060	0.0074	0.0083	0.0094	0.0101	0.0108
20.9	93.44%	0.23%	0.0057	0.0071	0.0079	0.0090	0.0097	0.0103
21.0	93.68%	0.24%	0.0060	0.0074	0.0083	0.0094	0.0101	0.0108
21.1	93.91%	0.23%	0.0058	0.0071	0.0079	0.0090	0.0097	0.0104
21.2	94.14%	0.23%	0.0057	0.0071	0.0079	0.0090	0.0097	0.0103
21.3	94.37%	0.23%	0.0057	0.0071	0.0079	0.0090	0.0097	0.0103
21.4	94.60%	0.23%	0.0057	0.0071	0.0079	0.0090	0.0097	0.0103
21.5	94.82%	0.22%	0.0055	0.0068	0.0076	0.0086	0.0092	0.0099
21.6	95.05%	0.23%	0.0057	0.0071	0.0079	0.0090	0.0097	0.0103
21.7	95.27%	0.22%	0.0055	0.0068	0.0076	0.0086	0.0092	0.0099
21.8	95.50%	0.23%	0.0057	0.0071	0.0079	0.0090	0.0097	0.0103
21.9	95.72%	0.22%	0.0055	0.0068	0.0076	0.0086	0.0092	0.0099
22.0	95.94%	0.22%	0.0055	0.0068	0.0076	0.0086	0.0092	0.0099
22.1	96.15%	0.21%	0.0052	0.0065	0.0072	0.0082	0.0088	0.0094

Table C-1. NRCS Type 1A Rainfall Distribution								
Time (hour)	Cumulative rainfall	Incremental rainfall	Incremental rainfall depth (inches)					
			2-year	5-year	10-year	25-year	50-year	100-year
			2.50	3.10	3.45	3.90	4.20	4.50
22.2	96.37%	0.22%	0.0055	0.0068	0.0076	0.0086	0.0092	0.0099
22.3	96.58%	0.21%	0.0052	0.0065	0.0072	0.0082	0.0088	0.0094
22.4	96.80%	0.22%	0.0055	0.0068	0.0076	0.0086	0.0092	0.0099
22.5	97.01%	0.21%	0.0052	0.0065	0.0072	0.0082	0.0088	0.0094
22.6	97.22%	0.21%	0.0052	0.0065	0.0072	0.0082	0.0088	0.0094
22.7	97.43%	0.21%	0.0053	0.0065	0.0072	0.0082	0.0088	0.0095
22.8	97.64%	0.21%	0.0052	0.0065	0.0072	0.0082	0.0088	0.0094
22.9	97.84%	0.20%	0.0050	0.0062	0.0069	0.0078	0.0084	0.0090
23.0	98.04%	0.20%	0.0050	0.0062	0.0069	0.0078	0.0084	0.0090
23.1	98.25%	0.21%	0.0052	0.0065	0.0072	0.0082	0.0088	0.0094
23.2	98.45%	0.20%	0.0050	0.0062	0.0069	0.0078	0.0084	0.0090
23.3	98.65%	0.20%	0.0050	0.0062	0.0069	0.0078	0.0084	0.0090
23.4	98.84%	0.19%	0.0047	0.0059	0.0066	0.0074	0.0080	0.0085
23.5	99.04%	0.20%	0.0050	0.0062	0.0069	0.0078	0.0084	0.0090
23.6	99.24%	0.20%	0.0050	0.0062	0.0069	0.0078	0.0084	0.0090
23.7	99.43%	0.19%	0.0048	0.0059	0.0066	0.0074	0.0080	0.0086
23.8	99.62%	0.19%	0.0048	0.0059	0.0066	0.0074	0.0080	0.0086
23.9	99.81%	0.19%	0.0048	0.0059	0.0066	0.0074	0.0080	0.0086
24.0	100.00%	0.19%	0.0048	0.0059	0.0066	0.0074	0.0080	0.0086

Appendix D: Design Concepts

Figures from Attachments A, B, C, and F of Drainage Master Plan (Otak 2010)

Attachment A — Illustration Showing LIDA Applied to Residential Lots

Multi-Family Residential / Stormwater Detention, Treatment & Infiltration

July 2, 2007

Washington County - North Bethany - Green Design Solutions

GREENWORKS

Single Family Residential / Stormwater Detention, Treatment & Infiltration; Rainwater Harvesting

Parking Lot / Impervious Surface Reduction & Stormwater Treatment

July 2, 2007

Washington County - North Bethany - Green Design Solutions

GREENWORKS

Attachment B — Illustrations Showing LIDA Applied to Streets

otak


PARKING
QUEUING LANE
PARKING
WIDTH VARIES
SIDEWALK
TRAVEL LANE
CURB BUMP OUT/ INFILTRATION PLANTERS
TRAVEL LANE
RESIDENTIAL LOCAL STREET
WIDTH VARIES
CURB BUMP OUT/ INFILTRATION PLANTERS
SIDEWALK

LIDA STREET CONCEPTS | LOCAL STREET - Mixed-Use/Commercial/Retail

North Bethany

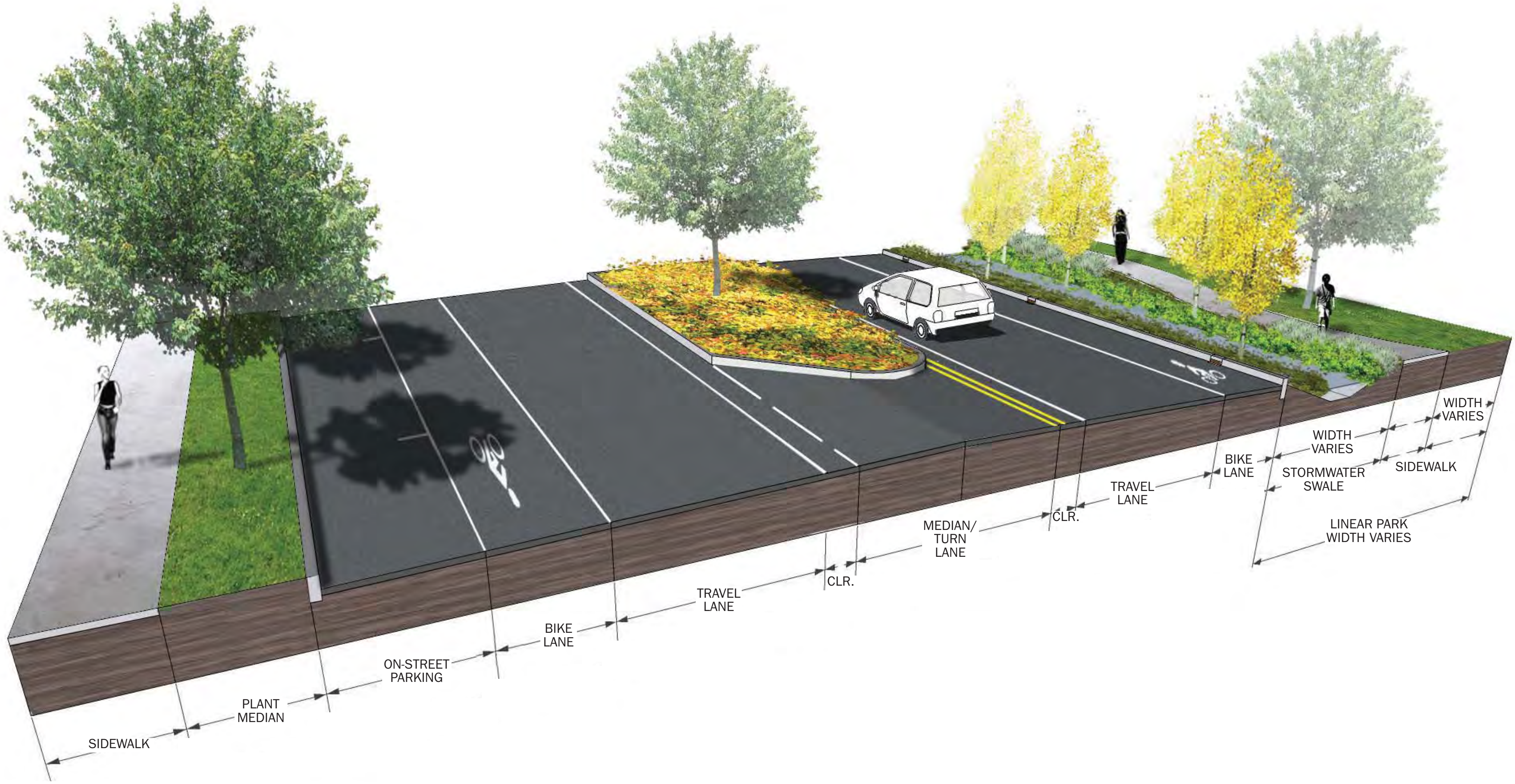
June 29, 2009

GREENWORKS

LIDA STREET CONCEPTS | 3-LANE ARTERIAL (Future 5-Lane Arterial)

North Bethany

June 29, 2009 GREENWORKS



LIDA STREET CONCEPTS | 3-LANE ARTERIAL (Future 5-Lane Arterial)

North Bethany

June 29, 2009

LIDA STREET CONCEPTS | PARK BLOCKS

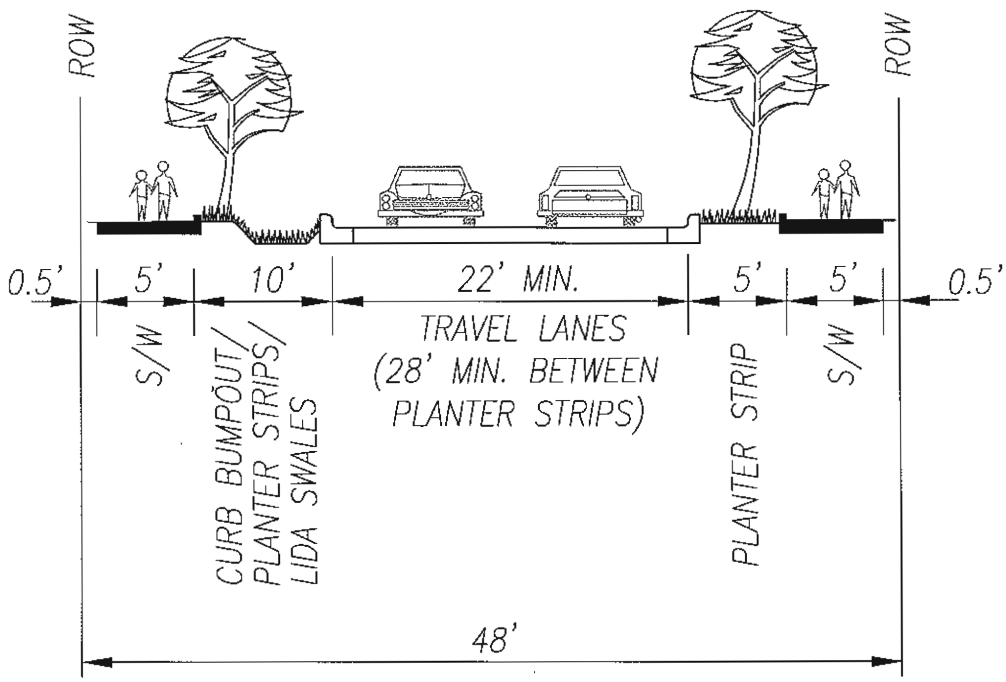
North Bethany

June 29, 2009

GREENWORKS

Attachment C — North Bethany Street Cross-Sections

NORTH BETHANY
LOCAL STREET
RESIDENTIAL



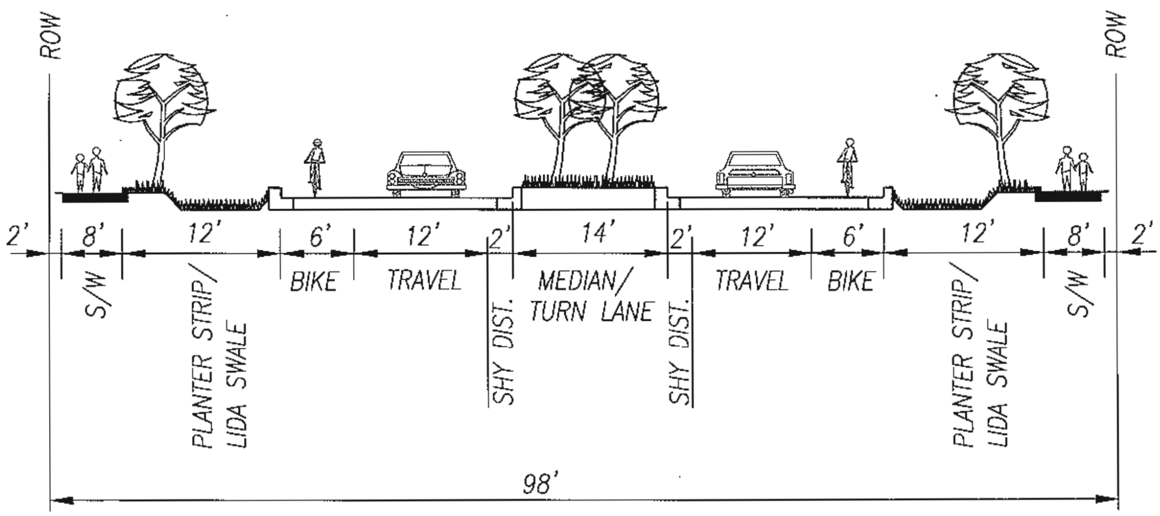
CRITERIA	LOCAL - 2 LANE
VEHICLE LANES WIDTH:	22 FT. MIN. (BETWEEN BUMP OUTS) 28 FT. MIN. (BETWEEN PLANTER STRIPS)
ON STREET PARKING:	YES/ALTERNATE WITH CURB BUMPOUT
BICYCLE LANES:	NONE
SIDEWALKS:	5 FT. MIN.
CURB BUMP OUT/LIDA SWALE/PLANTERS	10 FT.
LANDSCAPE STRIPS/LIDA SWALE:	4 FT. MIN. / 7 FT. SWALE MIN.
MEDIANS/TURN LANE WIDTHS:	NONE
NEIGHBORHOOD TRAFFIC MANAGEMENT:	YES

NOTE: SWALES TO CONFORM WITH CWS LIDA REQUIREMENTS.

WASHINGTON COUNTY OREGON — DEPARTMENT OF LAND USE AND TRANSPORTATION	PROJECT NUMBER	NORTH BETHANY CONCEPTS STREET CROSS SECTIONS WASHINGTON COUNTY, OREGON
	100074	NORTH BETHANY LOCAL STREET - RESIDENTIAL

PATH: O:\100074\PRESENT DWGS\ CAD: NBETHANY.DWG, TAB: NBTPU6 PLOT STAMP: 06/03/09 3:50P KELLYE

NORTH BETHANY
ARTERIAL (KAISER)
(SPRINGVILLE TO MAIN STREET)



CRITERIA

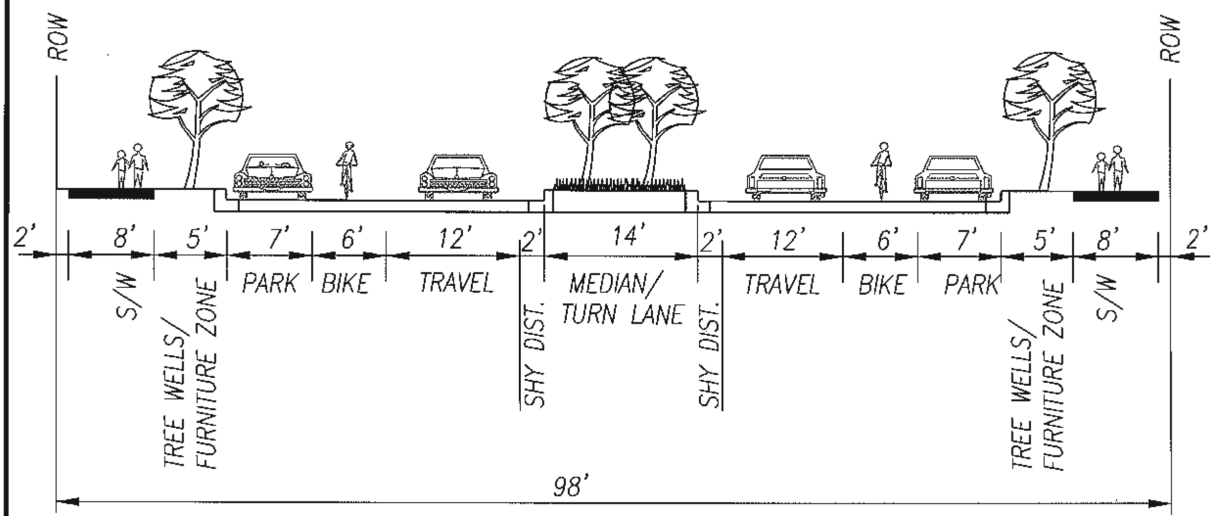
VEHICLE LANE WIDTHS:	12 FT.
ON STREET PARKING:	NONE
BICYCLE LANES:	6 FT.
SIDEWALKS:	8 FT.
PLANTER STRIPS/LIDA SWALE:	12 FT. / 7 FT. SWALE MIN.
MEDIANS/TURN LANE WIDTHS:	12 FT. – 16 FT.
NEIGHBORHOOD TRAFFIC MANAGEMENT:	NOT APPROPRIATE

NOTES:
- 20 FT. CLEAR BETWEEN PARKING AND RAISED MEDIAN FOR EMERGENCY RESPONSE REQUIRED.
- SWALES TO CONFORM WITH CWS LIOA REQUIREMENTS.

DEPARTMENT OF LAND USE AND TRANSPORTATION	PROJECT NUMBER	NORTH BETHANY CONCEPTS STREET CROSS SECTIONS WASHINGTON COUNTY, OREGON
	100074	ARTERIAL (KAISER) (SPRINGVILLE TO MAIN STREET

PATH: O:\100074\PRESENT DWGS\ CAD: NBETHANY.DWG, TAB: NBKA PLOT STAMP: 06/03/09 2:31P KELLYE

NORTH BETHANY
ARTERIAL (KAISER)
(MAIN STREET)



CRITERIA

VEHICLE LANE WIDTHS:	12 FT.
ON STREET PARKING:	7 FT.
BICYCLE LANES:	6 FT.
SIDEWALKS:	8 FT.
TREE WELLS/ FURNITURE ZONE	5 FT.
MEDIANS/TURN LANE WIDTHS:	12 FT. – 16 FT.
NEIGHBORHOOD TRAFFIC MANAGEMENT:	NOT APPROPRIATE

NOTE: 20 FT. CLEAR BETWEEN PARKING AND RAISED MEDIAN FOR EMERGENCY RESPONSE REQUIRED.

WASHINGTON COUNTY OREGON — DEPARTMENT OF LAND USE AND TRANSPORTATION	PROJECT NUMBER	NORTH BETHANY CONCEPTS STREET CROSS SECTIONS WASHINGTON COUNTY, OREGON
	100074	ARTERIAL (KAISER) (MAIN STREET)

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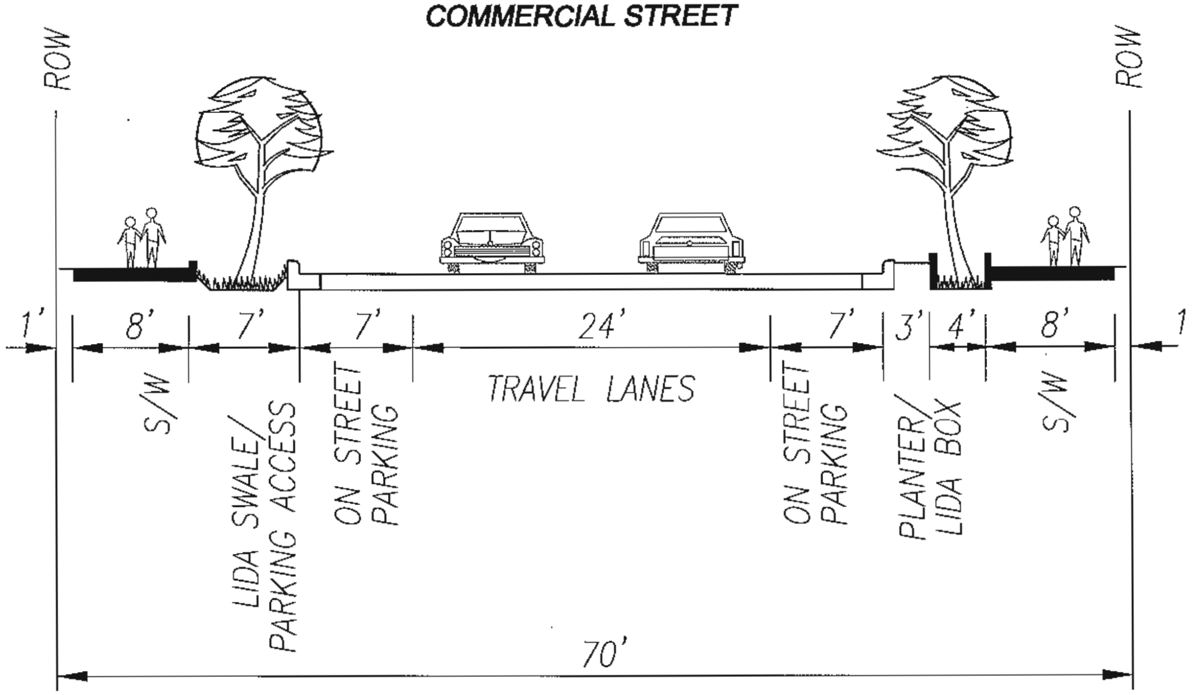
NORTH BETHANY
COMMERCIAL STREET



CRITERIA

VEHICLE LANES WIDTH:	12 FT.
ON STREET PARKING:	7 FT.
BICYCLE LANES:	SHARED
SIDEWALKS:	8 FT.
LANDSCAPE STRIPS/LIDA SWALE: ALT. – LIDA PLANTER BOX	4 FT. – 7 FT. SWALE MIN.
PARKING ACCESS:	0 – 3 FT.
MEDIANS/TURN LANE WIDTHS:	NONE
NEIGHBORHOOD TRAFFIC MANAGEMENT:	NOT APPLICABLE

NOTE: SWALES TO CONFORM WITH CWS LIDA REQUIREMENTS.

DEPARTMENT OF LAND USE AND TRANSPORTATION	PROJECT NUMBER	NORTH BETHANY CONCEPTS STREET CROSS SECTIONS WASHINGTON COUNTY, OREGON
	100074	NORTH BETHANY COMMERCIAL STREET

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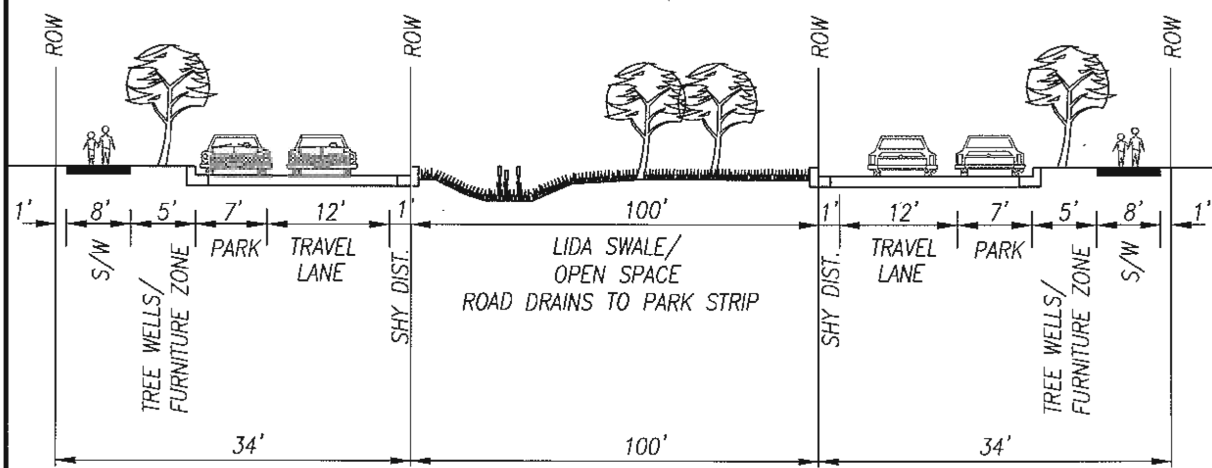
NORTH BETHANY
PARK BLOCKS



CRITERIA

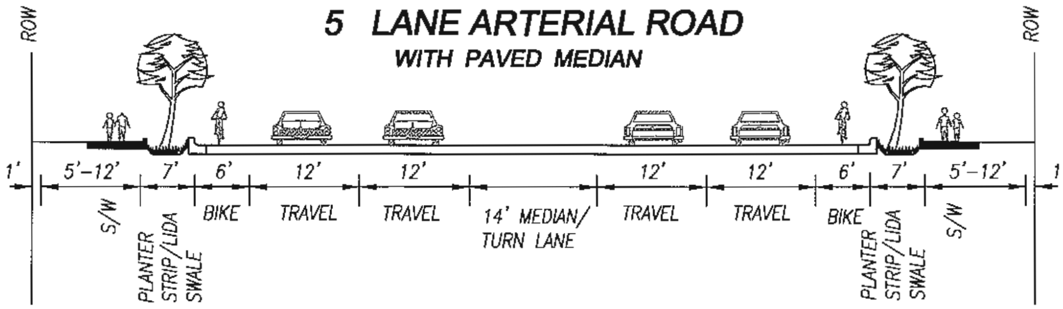
VEHICLE LANE WIDTHS:	12 FT. (ONE-WAY)
ON STREET PARKING:	7 FT.
BICYCLE LANES:	SHARED
SIDEWALKS:	8 FT.
TREE WELLS/ FURNITURE ZONE	5 FT.
MEDIANS/TURN LANE WIDTHS:	NONE
NEIGHBORHOOD TRAFFIC MANAGEMENT:	NOT APPROPRIATE

NOTES:
- 20 FT. CLEAR BETWEEN PARKING AND RAISED MEDIAN FOR EMERGENCY RESPONSE REQUIRED.
- SWALES TO CONFORM WITH CWS LIDA REQUIREMENTS.

WASHINGTON COUNTY OREGON — DEPARTMENT OF LAND USE AND TRANSPORTATION	PROJECT NUMBER	NORTH BETHANY CONCEPTS STREET CROSS SECTIONS WASHINGTON COUNTY, OREGON
	100074	NORTH BETHANY - PARK BLOCKS (ONE-WAY COUPLET)

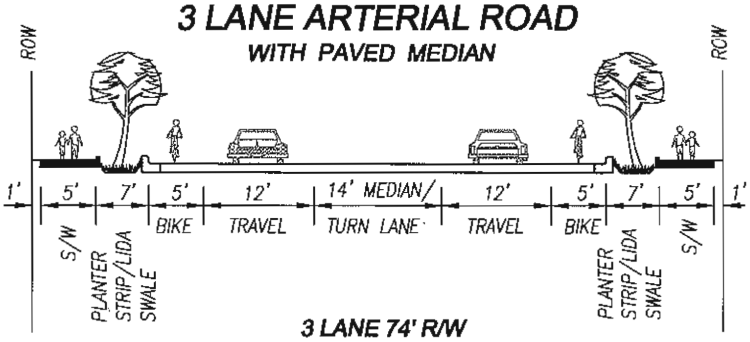
PATH: O:\100074\PRESENT DWGS\ CAD: NBETHANY.DWG, TAB: NBPB PLOT STAMP: 06/03/09 2:09P KELLYE

NORTH BETHANY
5 LANE ARTERIAL ROAD
WITH PAVED MEDIAN



5 LANE 98'-112' R/W

3 LANE ARTERIAL ROAD
WITH PAVED MEDIAN



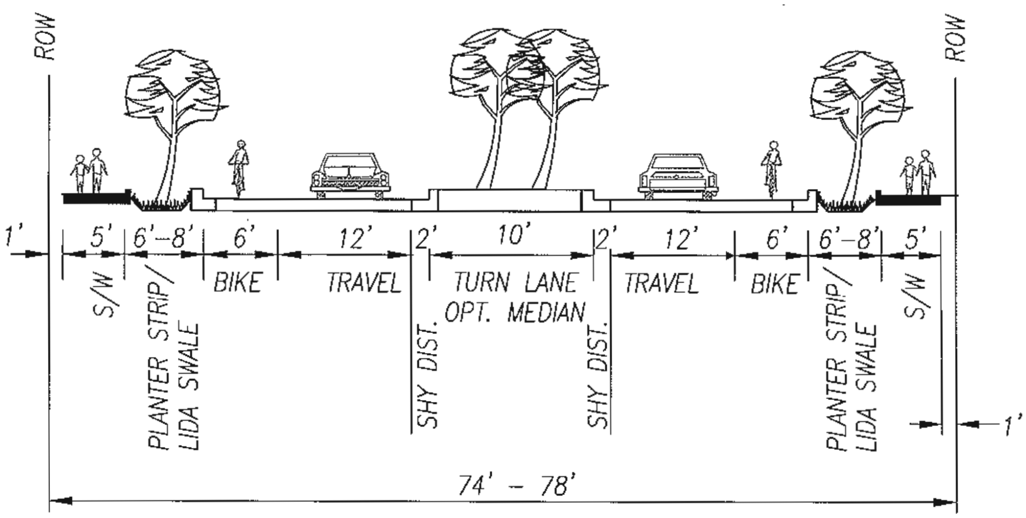
3 LANE 74' R/W

CRITERIA	5 LANE ARTERIAL ROAD	3 LANE ARTERIAL ROAD
VEHICLE LANE WIDTHS:	12 FT.	12 FT.
ON STREET PARKING:	NONE	NONE
BICYCLE LANES:	6 FT.	5–6 FT.
SIDEWALKS:	5–12 FT.	5–7 FT.
LANDSCAPE STRIPS/LIDA SWALE:	4 FT./7 FT. SWALE MIN.	4 FT./7 FT. SWALE MIN.
MEDIANS/TURN LANE WIDTHS:	14 FT.	14 FT.
NEIGHBORHOOD TRAFFIC MANAGEMENT:	NOT APPROPRIATE	NOT APPROPRIATE

NOTES: – 20 FT. CLEAR BETWEEN PARKING AND RAISED MEDIAN FOR EMERGENCY RESPONSE REQUIRED.
– SWALES TO CONFORM WITH CWS LIDA REQUIREMENTS.

WASHINGTON COUNTY OREGON — DEPARTMENT OF LAND USE AND TRANSPORTATION	PROJECT NUMBER: 100074	NORTH BETHANY CONCEPTS STREET CROSS SECTIONS WASHINGTON COUNTY, OREGON — 5 & 3 LANE ARTERIALS WITH PAVED MEDIANS

NORTH BETHANY
3 LANE COLLECTOR



CRITERIA	3 LANE COLLECTOR
VEHICLE LANE WIDTHS:	12 FT. MIN.
ON STREET PARKING:	NONE
BICYCLE LANES:	6 FT.
SIDEWALKS:	5 FT. – 7 FT.
PLANTER STRIPS/LIDA SWALE:	4 FT. / 7 FT. SWALE MIN.
TURN LANE WIDTHS:	14 FT.
NEIGHBORHOOD TRAFFIC MANAGEMENT:	NOT APPROPRIATE

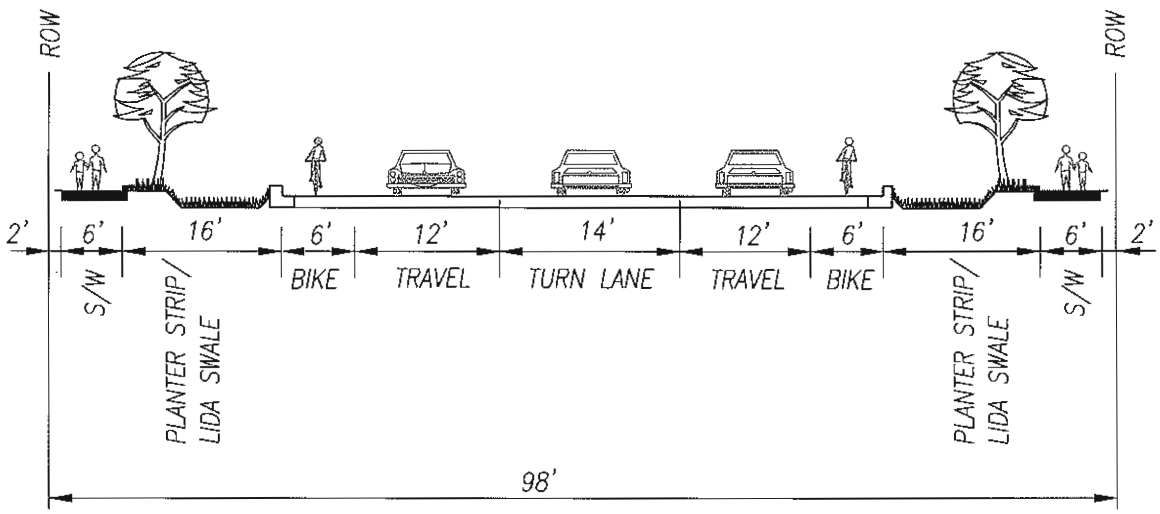
NOTES:
- 20 FT. CLEAR BETWEEN PARKING AND RAISED MEDIAN FOR EMERGENCY RESPONSE REQUIRED.
- SWALES TO CONFORM WITH CWS LIDA REQUIREMENTS.

WASHINGTON COUNTY OREGON — DEPARTMENT OF LAND USE AND TRANSPORTATION	PROJECT NUMBER	NORTH BETHANY CONCEPTS STREET CROSS SECTIONS WASHINGTON COUNTY, OREGON
	100074	NORTH BETHANY 3 LANE COLLECTOR WITH OPEN OPTION CONVEYANCE

PATH: O:\100074\PRESENT DWGS\ CAD: NBETHANY.DWG, TAB: NBTPU1A PLOT STAMP: 06/03/09 11:29A KELLYE

NORTH BETHANY ARTERIAL (KAISER)

(NORTH OF MAIN STREET)



CRITERIA

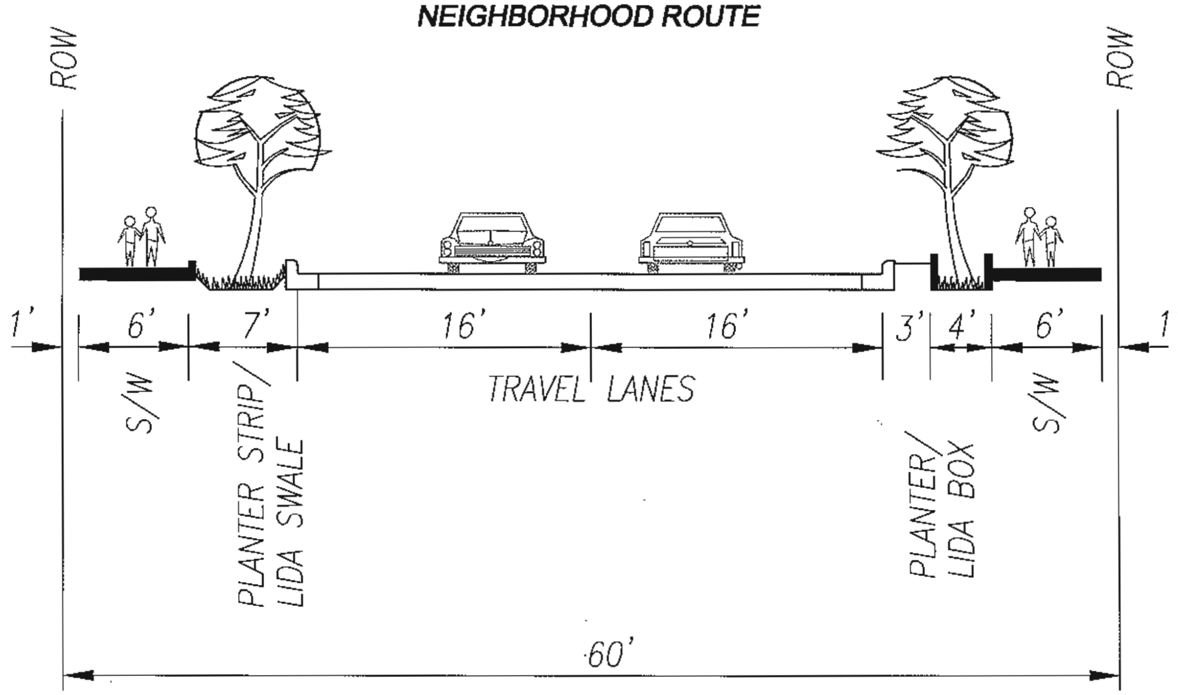
VEHICLE LANE WIDTHS:	12 FT.
ON STREET PARKING:	NONE
BICYCLE LANES:	6 FT.
SIDEWALKS:	6 FT.
PLANTER STRIPS/LIDA SWALE:	16 FT./7 FT. SWALE MIN.
MEDIANS/TURN LANE WIDTHS:	14 FT.
NEIGHBORHOOD TRAFFIC MANAGEMENT:	NOT APPROPRIATE

NOTE: SWALES TO CONFORM WITH CWS LIDA REQUIREMENTS.

WASHINGTON COUNTY OREGON — DEPARTMENT OF LAND USE AND TRANSPORTATION	PROJECT NUMBER	NORTH BETHANY CONCEPTS STREET CROSS SECTIONS WASHINGTON COUNTY, OREGON
	100074	ARTERIAL (KAISER) (NORTH OF MAIN STREET)

PATH: O:\100074\PRESENT DWGS\ CAD: NBETHANY.DWG, TAB: NBKC PLOT STAMP: 06/03/09 9:44A KELLYE

NORTH BETHANY
NEIGHBORHOOD ROUTE



CRITERIA

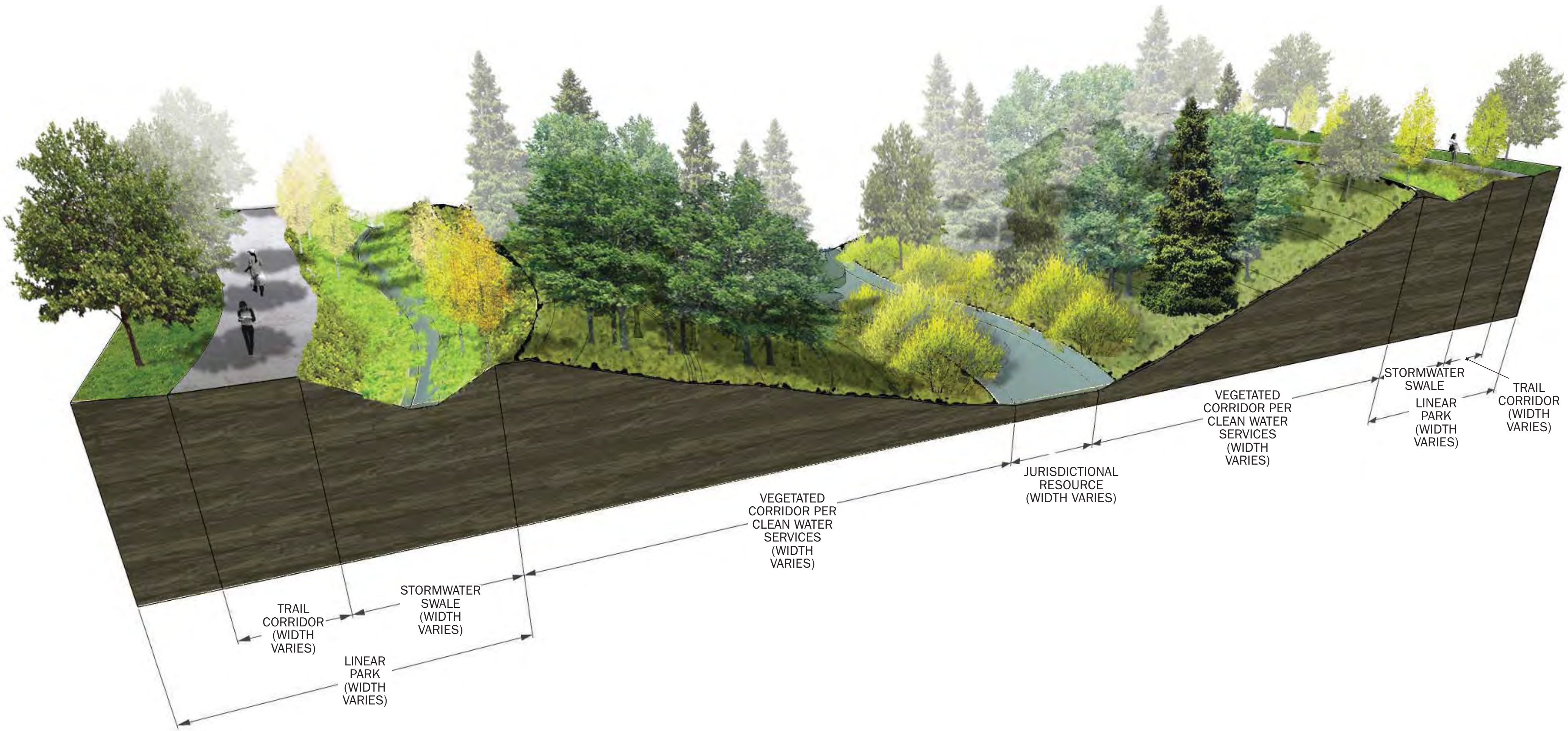
VEHICLE LANES WIDTH:	16 FT.
ON STREET PARKING:	SHARED
BICYCLE LANES:	SHARED
SIDEWALKS:	6 FT. – 13 FT.
LANDSCAPE STRIPS/LIDA SWALE: ALT. – LIDA PLANTER BOX	4 FT. – 7 FT. SWALE MIN.
MEDIANS/TURN LANE WIDTHS:	NONE
NEIGHBORHOOD TRAFFIC MANAGEMENT:	NOT APPLICABLE

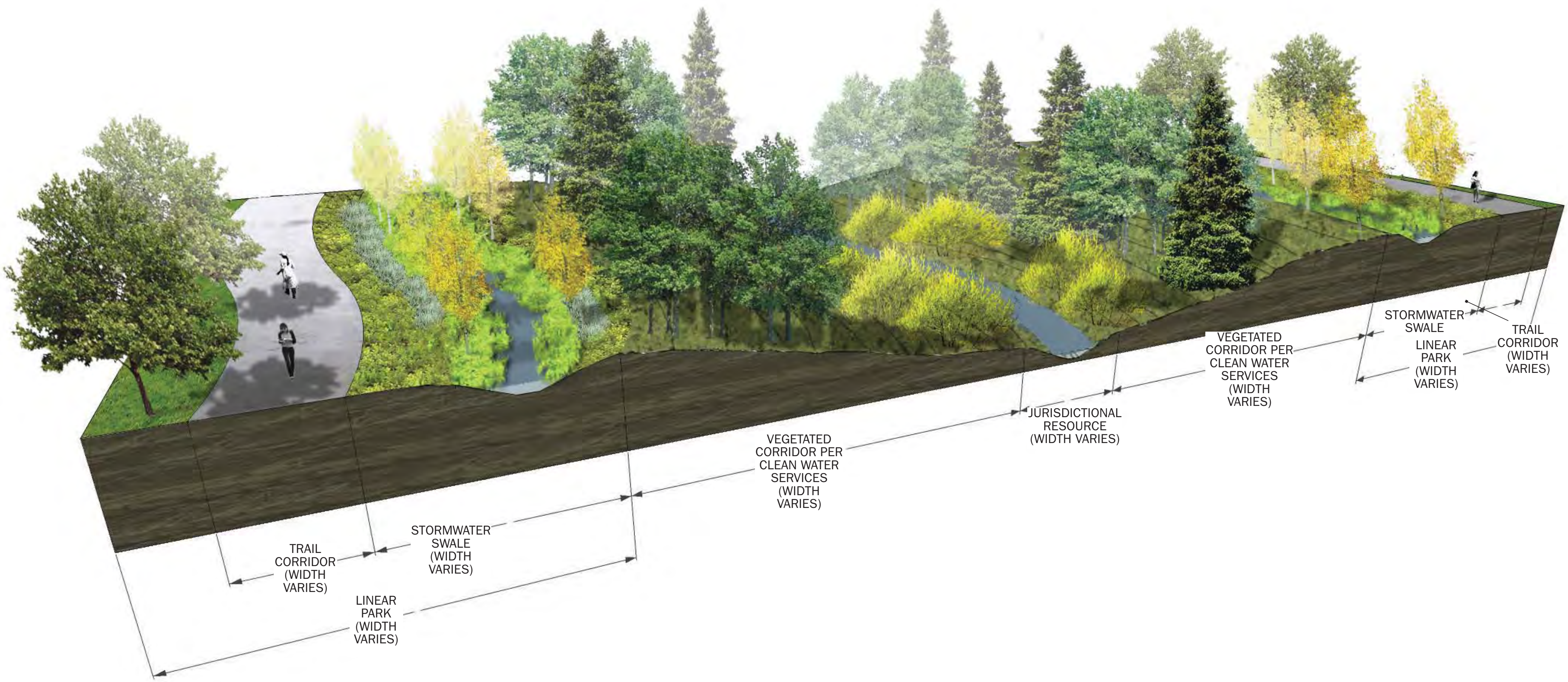
NOTE: SWALES TO CONFORM WITH CWS LIDA REQUIREMENTS.

WASHINGTON COUNTY OREGON DEPARTMENT OF LAND USE AND TRANSPORTATION	PROJECT NUMBER	NORTH BETHANY CONCEPTS STREET CROSS SECTIONS WASHINGTON COUNTY, OREGON
	100074	NORTH BETHANY NEIGHBORHOOD ROUTE

PATH: O:\100074\PRESENT DWGS\ CAD: NBETHANY.DWG, TAB: NB-NHR PLOT STAMP: 06/03/09 9:36A KELLYE

Attachment F — Illustrations Showing Linear Park Concepts with Regional Stormwater Facilities


TRAIL
CORRIDOR
(WIDTH
VARIES)
STORMWATER
SWALE
(WIDTH
VARIES)
LINEAR
PARK
(WIDTH
VARIES)
VEGETATED
CORRIDOR PER
CLEAN WATER
SERVICES
(WIDTH
VARIES)
JURISDICTIONAL
RESOURCE
(WIDTH VARIES)
VEGETATED
CORRIDOR PER
CLEAN WATER
SERVICES
(WIDTH
VARIES)
STORMWATER
SWALE
LINEAR
PARK
(WIDTH
VARIES)
TRAIL
CORRIDOR
(WIDTH
VARIES)



LIDA STREET CONCEPTS | LINEAR PARK - Bethany Creek

North Bethany

June 29, 2009 GREENWORKS