Penjajawoc Watershed BMP Retrofit Design Project

Penobscot County
Bangor, Maine

A low impact development approach to mitigate flow and runoff in the Penjajawoc Stream watershed

Final Report
3.13.2007

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Table of Contents

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Appendix A – Supplemental Items, Maps & Appendices

Figure A-1 Site Location Map
Figure A-2 Stream Reach Identification
FIRM Maps (3)
Table A-1 Referenced Record Document List
Figure A-3 Subwatershed Identification
Figure A-4 Proposed BMP Retrofit Subareas
Figure A-5 On-Site Soil Types
USDA Soil Maps (4)
HY101-108 Subwatershed Grid Maps

Appendix B – Hydrologic Modeling Results

Table B8 Subwatershed Attributes
Hydrocad Routing Diagram

Appendix C – MDEP LID BMPs

Introduction:

The Maine Department of Environmental Protection (MDEP) stormwater regulations in the past have focused on flood control and peak flow attenuation. Many older Best Management Practices (BMPs) in the Penjajawoc Watershed perform according to these standards. More recently, focus shifted to water quality aspects and some recent BMPs were equipped to improve upon pollutant loading conditions (80% total suspended solids [TSS] removal). In November 2005, the MDEP concluded that the past methods were not performing in the desired manner. Studies found that the 1- or 2-year frequency events generally made the channel unstable, and that infrequent high flow events were not as damaging as once thought. As a result, the stormwater regulations were revised. Implementation is under way; however, few BMPs in the Penjajawoc Watershed are compliant with new Low Impact Development (LID) BMP standards.

MDEP contracted WBRC Architects / Engineers to perform a hydrologic analysis of the Penjajawoc Watershed and to propose four (4) new or retrofit LID storm water BMPs to improve the water quality of the stream during a baseline flow condition (up to 2-year storm) and to target hydrologic and pollutant goals listed in the TMDL. It should be noted that the Total Maximum Daily Load (TMDL) report for Penjajawoc Stream is not yet available.

Two (2) other firms were contracted to do parallel studies on the Penjajawoc Watershed. ENSR Corporation and Parish Geomorphic, Ltd. were retained to perform a SWMM model and geomorphologic analysis, respectively. Results of these studies were used in this report to augment base flow data in order to enable WBRC to provide a target 2-year hydrologic analysis. It should be noted that while WBRC was contracted to study only runoff directly entering the Penjajawoc Stream, both ENSR Corporation and Parish Geomorphic, Ltd. compiled data for two adjacent subwatersheds. In addition, a recent P-8 program report (Tetra Tech, 2003) was reviewed to support watershed ground cover and imperviousness values used in the Hydrocad model.

The purpose of this study was as follows:

1. Identify and calibrate target watersheds hydrology for critical storm flow using Hydrocad in conjunction with data obtained from recent SWMM modeling and geomorphic analysis. Incorporate use of archived hydrology data where possible to create the watershed model.
2. Review stream geomorphology results and SWMM model results to determine critical issues.
   - ☐ *Thermal*
   - ☐ *Pollutant Loading*
   - ☐ *Hydrology*
   - ☐ *Dissolved Oxygen*
4. Inventory existing BMPs and identify (4) BMP sites for implementation/remediation, incorporating LID techniques wherever possible.
5. Prepare a report for use by watershed managers and stakeholders to use as a guide for future development.

1.0 – General Findings & Background

1.1 – Watershed Characteristics:

The Penjajawoc Stream Watershed is a 5,600-acre watershed located to the northeast of Bangor, Maine in Penobscot County. The Penjajawoc Stream is 27,000 feet (5.2 miles) long and contains 10 tributaries, among which are Meadow Brook and Tributary #3 (Mt. Hope Cemetery). The upper watershed contains a large 300-acre emergent freshwater marsh known as Penjajawoc Marsh. This marsh is bisected by the now obsolete Veazie Railroad bed. (Figure 1.0) See also figure A-1 Site Location Map in Appendix A.

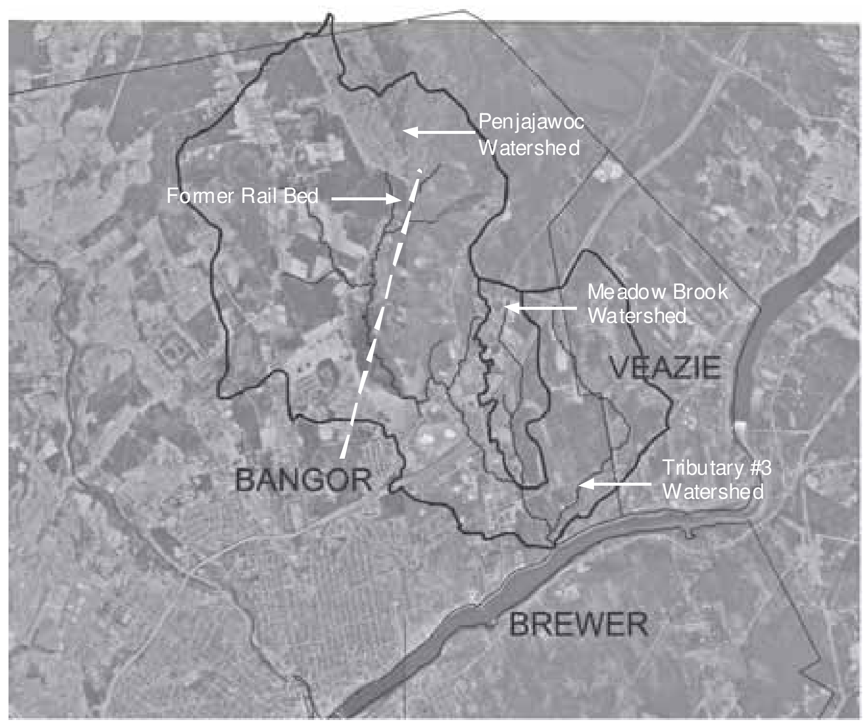

Figure 1.0 Watershed Location (USGS 1995 photo base)

The mouth of the stream is at elevation 1.81 feet NGVD.[1] The stream has a gentle slope with no reaches being steeper than 1% average slope. The highest point in the entire

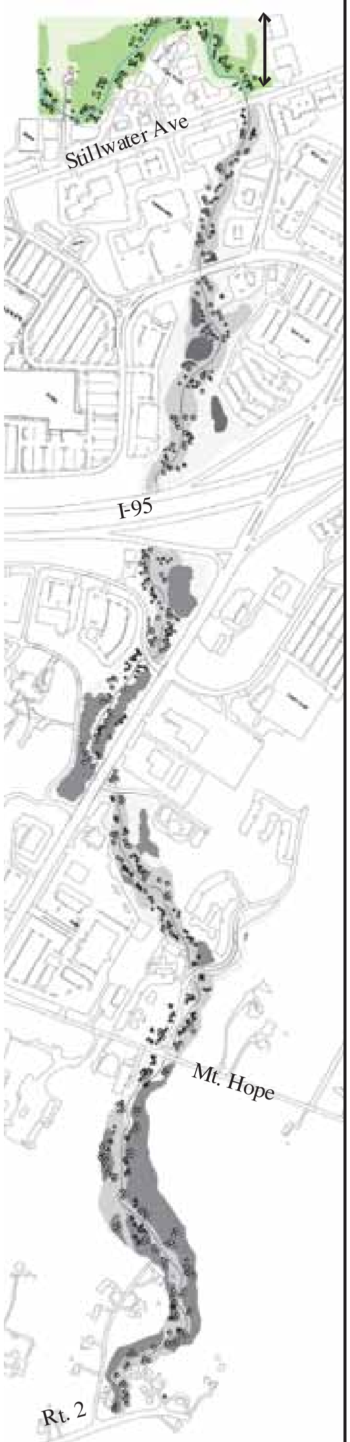

Figure 1.1 Upper Reaches

[1] The National Geodetic Vertical Datum of 1929 was used throughout this project.

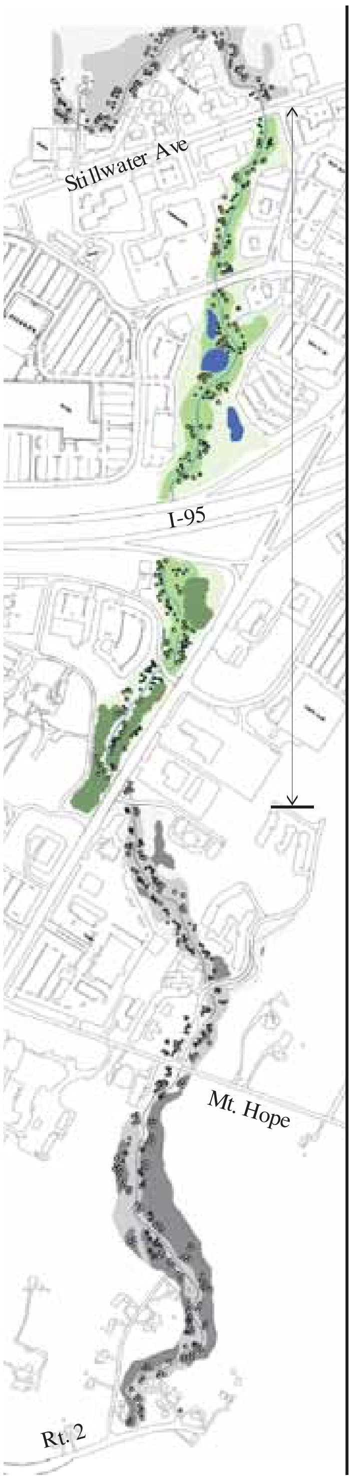

Figure 1.2 Middle Reaches

watershed is at elevation 300. See figure A-2 Stream Reach Identification in Appendix A for topographic reference material.

The Penjajawoc Watershed has been impacted by development in the past 30 years. The developed areas are expected to see continued growth, adding to the impervious coverage. The upper watershed is largely undeveloped and forested.

1.2 – Headwater Characteristics:

Penjajawoc Marsh lies to the north of the site and serves as a headwater to the stream. The marsh attenuates runoff from the upper watershed. It is part of a large system of bogs named for nearby Caribou Bog, which formed because of the flat elevation and poorly drained soil types of the surrounding area. Much of the acreage of Penjajawoc Marsh is owned by the City of Bangor.[2] It should be noted that Penjajawoc Marsh is an area of conservation interest because it serves as a refuge for migratory waterfowl.

1.3 – Stream Characteristics:

The Penjajawoc Stream is classified as a Class B water body under the Maine Water Quality Standards classification of fresh surface waters and designated uses. For the purpose of this study, the upper reach includes the 3,463-acre tributary above the Stillwater Avenue road crossing (sta. 10+111), and its land coverage includes the aforementioned 300-acre Penjajawoc Marsh. (Figure 1.1) The middle reaches of the stream flow through a developed urban area, causing this stream to be 303(d) listed for statutory impairments to aquatic life due to non-point sources.[3] (Figure 1.2)

The Penjajawoc Stream flows directly into the Penobscot River, which behaves as mild tidewater at the stream exit site. (Figure 1.3) The Penobscot River continues into the Gulf of Maine. The mouth of the Penjajawoc Stream contains an alluvial delta. Aerial photography suggests that

2 Maine Natural Areas Program
3 Maine Water Quality Standards, 1998 303(d) list

this deposit has indeed come from the Penjajawoc; additional inspection during June of 2006 led to the tentative conclusion that the delta has been present for many years, but shifts position periodically.

As shown on the Flood Insurance Rate Maps (FIRM, included in Appendix A), many places in the watershed are susceptible to flooding. There is beaver activity throughout the watershed that also contributes to localized flooding. (Figure 1.4)

The stream channel is estimated to have changed several times over the years, both from natural processes and from human activity. The developed area was formerly a dairy farm and some segments may have been flattened and straightened to accommodate the farming needs. More recently, development has encroached upon the banks, causing similar changes. Stream crossings were installed where needed. Several tributaries have been diverted through culverts and a segment of the Penjajawoc appears to have been filled to accommodate a parking lot.

Figure 1.3 Lower Reaches

1.4 – Highlights of Parallel Studies:

- **Parish Geomorphic, Ltd.:**

During July of 2005 to November of 2005, Parish Geomorphic, Ltd. conducted a geomorphologic study of the stream channel, which consisted of an existing conditions inventory, erosion pin and cross section monitoring, interpretation, and recommendations.

Fluvial geomorphology is defined as "the study of…landform development as influenced by moving water such as rivers and streams."[4] Before conducting the current evaluation, Parish conducted a preliminary report in 2003. This report concluded that the stream channel had been adjusting to accommodate the effects of land use change. These changes were both directly fabricated and gradual channel alterations. The report recommended additional monitoring and suggested preliminary stream restoration practices such as bank erosion control and effective stormwater management.

[4] Endreny

Figure 1.4 Present or former beaver activity

The 2006 report entailed analysis of stream adjustment at six cross sections, three of which were in the Penjajawoc channel (the others being in tributaries). The report measured the change in cross sectional area and attempted to accurately portray stream bankfull conditions and critical conditions. Parish defines "bankfull" conditions as the level of flow, corresponding to approximately the 1.5- to 2-year storm event, at which the flow fills the stream channel but does not spill into the flood plain. Stream "critical" conditions are defined as the discharge where the average-size particle begins to move, and hence the stream begins to erode.

Parish divided the stream main channel into 13 reaches, which are shown in the following table according to the station at which they start. For reference, refer to figure A-2 in Appendix A.

TABLE 1.0 – PARISH REACH LOCATIONS

PARISH REACH	STARTING STATION
PS-1	0+000
PS-2	0+950
PS-3	3+700
PS-4	5+400
PS-5	7+250
PS-6	8+900
PS-7	10+000
PS-8	12+500
PS-9	13+700
PS-10	15+650
PS-11	20+100
PS-12	23+100
PS-13	24+300
End	27+255

In addition to monitoring stream cross-sections, erosion pins were used to evaluate rates of channel adjustment. The pins demonstrated a low level of channel change but additional monitoring was recommended. The results led to the conclusion that, while the stream is

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currently undergoing slow transition, stream features suggest past disturbances. It was concluded that the stream was behaving as an urban system.

Parish observed that the upper and middle reaches of the stream channel are wide and shallow, causing the stream to move slowly and to lose sediment. As a result, stream aggradation is occurring. Aggradation is the process by which a stream deposits sediment. This condition was reversed in the lower reaches, as degradation occurred because of a narrower stream channel, steeper channel slopes, and increasing flow rates. Degradation is simply the opposite of aggradation, in which the stream erodes sediment. Parish recommended detailed stream bank restoration techniques for specific reaches in the stream and its tributaries. Additional monitoring was also recommended to obtain a long-term estimate of trends.

The Penjajawoc Stream was found to have issues of channel migration, bank erosion, and sediment accumulation. The critical issue outlined in the geomorphic analysis was the fact that erosion and deposition trends need to be addressed; otherwise, water quality, aquatic habitat, and infrastructure may become threatened.

- **ENSR Corporation:**

ENSR Corporation conducted a Storm Water Management Model (SWMM) using similar watershed parameters as WBRC, which are described in supplemental information in Appendix B. The SWMM model analyzes the buildup, washoff, and treatment of typical stormwater pollutants and predicts average runoff and stream flow on an annual basis. Among the modeling assumptions by ENSR were constant hydrologic soil group “C”, uniform trapezoidal stream channel geometry, pervious and impervious land use types, and statistically average rainfall conditions. Buildup-washoff and removal/treatment expressions were derived for seven (7) pollutant parameters:

- total suspended solids (TSS);
- phosphorus (P);
- total Kjeldahl nitrogen (TKN);
- zinc (Zn);
- copper (Cu);
- lead (Pb);
- petroleum hydrocarbons (HC).

Similar parameters were used by Tetra Tech, Inc. in a P8 Model prepared for Penjajawoc Stream in 2003. Results represent average conditions over an annual period.

Results were compiled for four points of interest on the stream:

- 0+000 – Confluence with Penobscot River (mouth of stream);
- 3+740 – At the confluence of Meadow Brook;
- 7+220 – At I-95 culvert, downstream of Bangor Mall;
- 10+080 – Downstream of headwater wetland (Stillwater Ave. crossing).

ENSR concluded the SWMM report with an expression of total annual pollutant loads under existing conditions. See figure A-2 in Appendix A for locations of stations.

TABLE 1.1 – SWMM RESULTS

	ANNUAL LOAD (LBS)			
POLLUTANT	10+080	7+220	3+740	0+000
TSS	370.00	990.00	1,500.00	1,590.00
P	2.60	5.40	8.20	8.80
TKN	13.00	27.00	41.00	44.00
Cu	0.31	0.62	0.93	1.00
Pb	0.10	0.23	0.35	0.38
Zn	1.40	2.90	4.40	4.70
HC	12.00	29.00	44.00	47.00

The SWMM model did not attempt to diagnose any critical issues; instead, ENSR intended the model to be used to compare existing conditions with potential improvements in the future. The model would have to be updated as additions or deletions to existing BMPs took place. The results were to be used for comparison of potential scenarios in addition to actual future conditions.

1.5 – Groundwater Depth:

To aid in the prediction of maximum and minimum expected groundwater flows as visible in stream baseflow, or exiting from underdrained storm systems, data from a USGS groundwater monitoring station in Kenduskeag was reviewed. The following table highlights the wettest and driest part of the seasonal groundwater, noted as the lowest and highest values, respectively. As an example, underdrain flow observed exiting the Bangor Mall drainage system during late August is measured to be at its lowest flow rate. Additional monitoring should be conducted in April of the following season.

TABLE 1.2 DEPTH TO GROUNDWATER (FEET)

Average		Minimum		Maximum	
Month	Total	Month	Total	Month	Total
Jan	21.91	Jan	16.84	Jan	26.98
Feb	21.99	Feb	17.08	Feb	26.70
Mar	20.89	Mar	15.09	Mar	25.02
Apr	**18.77**	**Apr**	**14.92**	Apr	22.89
May	19.83	May	16.13	May	22.29
Jun	21.36	Jun	16.58	Jun	23.45
Jul	22.75	Jul	18.79	Jul	24.63
Aug	23.74	Aug	20.43	Aug	25.45
Sep	**24.53**	Sep	20.96	Sep	26.91
Oct	24.31	Oct	17.85	Oct	26.58
Nov	23.13	Nov	17.48	Nov	27.08
Dec	21.96	Dec	15.76	**Dec**	**27.32**
Average	22.08	Average	17.33	Average	25.44

2.0 – Hydrologic Model

2.1 – Methods and Assumptions:

A hydrology model using the Hydrocad v. 7.10 computer model was developed using TR-20 and TR-55 methodologies. This model was chosen due to the ability to input existing (Hydrocad) record data, the need to permit future developments to access and modify the model, to determine the appropriate timing of discharge, and to guide BMP selection. Approximately 275 record drawings were scanned for use in developing a current representation of the watershed characteristics. See table A-1 in Appendix A listing the record documents used in this report.

With the exception of three contributing subareas, time of concentration (Tc), coverage (CN), and time of travel (Tt) were developed to build and calibrate the model to match observations. Due to the complexities of the headwater tributary (above Stillwater Avenue), and the natural attenuation of the Penjajawoc Marsh, wooded areas, and organic layers within, a stream base flow was assigned based on the Parish Geomorphic observation in lieu of a standard hydrograph. Since the timing of the runoff from the wooded areas and marsh lag the peak period of the lower developed watersheds, this approach appeared to calibrate best with observed conditions for the 1- and 2-year storm events. Although outside the scope of this study, runoff from Meadow Brook and the Tributary #3 were similarly assigned a base flow value to permit calibration of the stream model with other published results (FIRM) at the confluence with the Penobscot River.

Since prior hydrologic models for new development were typically developed on a subarea-by-subarea basis, they rarely analyzed the cumulative effect of BMP development to overall stream peak flow timing or intensity. Tabular results of this analysis are contained in section 2.3.

Hydrocad offers three routing methods for its hydrologic modeling system: the "storage-indication" method, the "dynamic-storage-indication" method, and the simultaneous routing method. The storage-indication method is a sequential procedure in which each node (reach or pond) is calculated one-at-a-time in a fixed order. This technique, while being fast and widely accepted, does not allow for tailwater conditions. In the dynamic-storage-indication method, the nodes are also calculated in a sequential order. However, in this method, each node is re-evaluated at each time step, allowing upstream nodes to respond to changing tailwater conditions. The simultaneous method is used when a flow order is not necessary or not known. This method is intended for use only with certain special conditions, such as tidewater effects.

For this analysis, the "dynamic-storage-indication" method was selected to observe the effects of tailwater on subarea runoff and to model step-backwater conditions with minimal flow oscillation.

In this study, the impact to stream peak flow of each BMP retrofit was analyzed in the model to optimize 1- and 2-year discharge rates, and to monitor unintentional downstream flooding and peak flow rates for 10-, 25-, and 100-year storm events.

Since the base flows assigned for the headwater and tributaries were representative of observed conditions at the time of this study, it is recommended that stream flow gauging be conducted on a regular basis to provide accurate base flow data for the hydrologic model. As LIDs are developed to mimic natural stream base flow, stream capacity to handle stormwater events within the 2-year bankfull/critical depth will decrease, affecting decisions for implementing future BMP selection.

Retrofit of a typical wet/dry detention basin outlet to control a 1-year event vs. a 2-year event will alter its stage/storage curve, resulting in a system that could begin to reach its capacity prior to the original 25-year design event. It is therefore important that all BMP pond retrofits affecting stormwater storage be modeled within this program set to prevent unintentional downstream flooding and erosion. We strongly encourage the creation of a watershed coordinator position. This individual should be responsible for ensuring that the hydrologic model is properly updated for any development occurring within the Penjajawoc Watershed.

2.2 – Limitations of the Hydrologic Model

1. The impact of beaver dam activity was discussed jointly with MDEP and the consultant teams. It was decided that this phenomenon was unpredictable, and if necessary, could be corrected to restore the stream to the anticipated target condition. The model did not identify these structures within stream reaches.

2. Dt was adjusted to 0.05 hours to remove any latent oscillations within the hydrograph output.

3. Calibration of the model consisted of visual observations of bank-full erosion depths, scour line indicators on culverts and below road crossings, and comparison to other published data (FIRM).

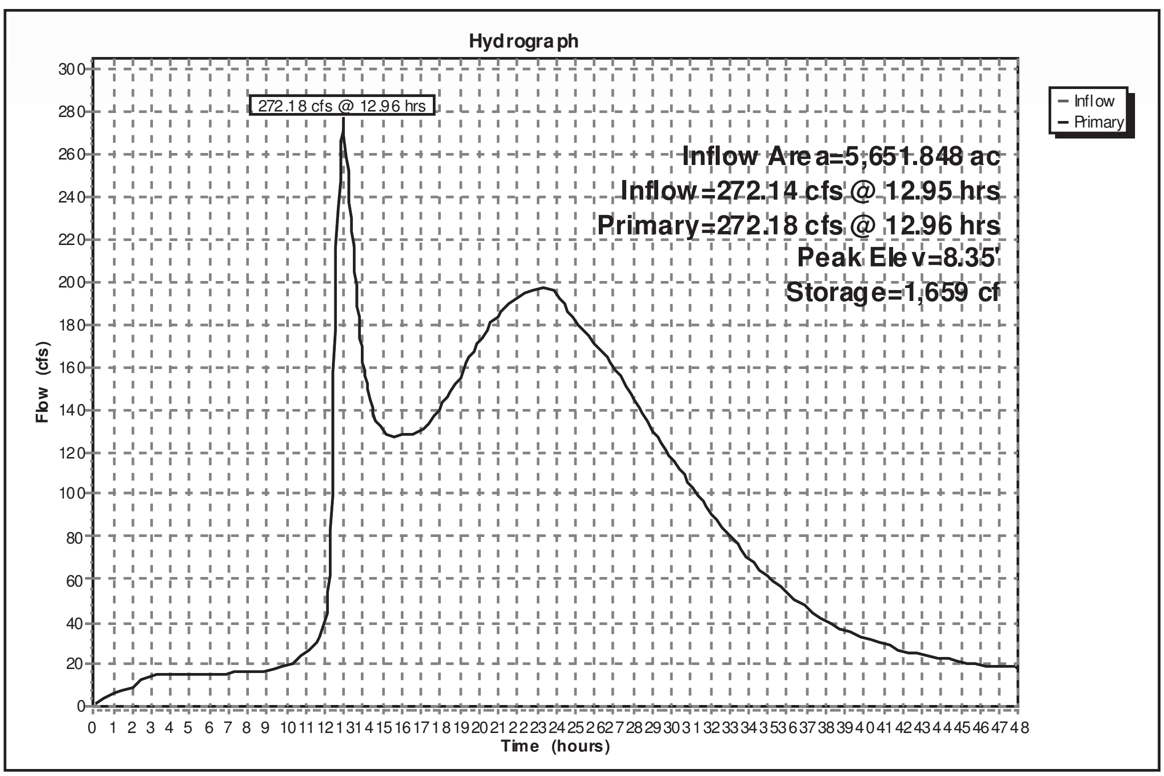
4. The 36' span bridge serving Bangor Federal Credit Union was omitted from the model due to the fact that a prior HEC-2 analysis of the structure determined that the flooding impact to the 32' wide floodway in a 100-year event would be less than 0.2'. As such, there was no appreciable ponding or attenuation of stream flow at this structure during 1- and 2-year events.

5. Stage-storage relationships were determined using city digital and record drawing topography at road crossings. A field survey of impounded areas was not conducted.

6. Field data collected for road crossings was limited to inlet invert, outlet invert, size, condition, type, length, and observed tailwater depth during June of 2006. Scour lines were photographically documented with a vertical scale reference.

7. Use of the "upland" method outlined in NEH-4 to determine the approximate time of concentration (Tc) of the headwater (above Stillwater Avenue) gave a watershed lag time of 5 hours. Estimates of lag times using Hydrocad gave lag times of 9.85 hours for the upper watershed, 7 hours for Tributary #3, and 2.7 hours for Meadow Brook. The total lag time was found to be approximately 10 hours. (See table 2.0 below.) It was determined that these tributary outflows could be omitted to permit focus on developed watershed peak runoff since peak flow amounts will not be interfering with one another. Record documents have also indicated that this is the case; inspection of SLODA from past projects in the developed area found that other firms had made a similar assumption.

<u>TABLE 2.0 WATERSHED PEAK FLOW WITH OUT-OF-SCOPE TRIBUTARIES (1-YEAR STORM; ASSUMED Tc, CN)</u>



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The first peak represents the peak outflow from the developed middle reach section. The second, broader peak represents the attenuated inflow from the wooded tributaries due to the lag time from the tributary areas. The overall first peak flow increased by a mere 2 cubic feet per second (cfs) with the addition of the estimated tributary flows. The value shown in this graph should not be taken as exact; stream flows from these out-of-scope tributaries should be gauged to verify the assumptions in this and other reports.

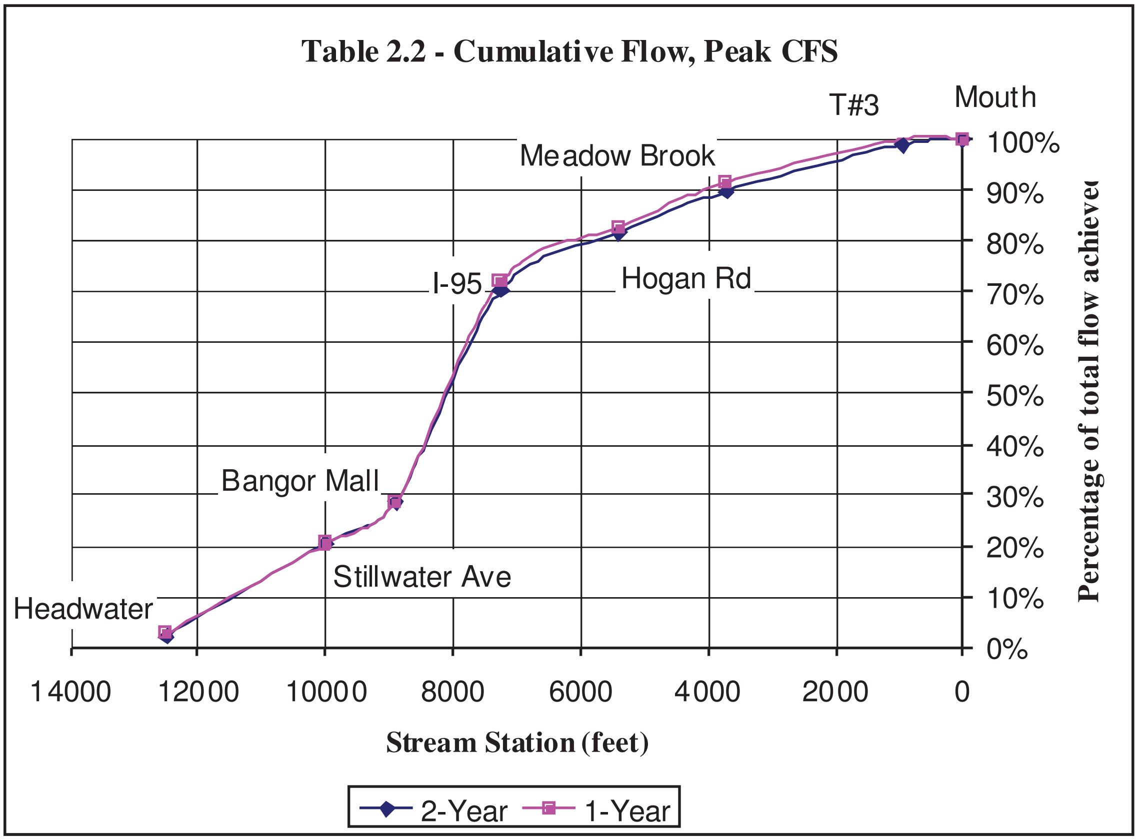
2.3 – Results of Hydrologic Model:

The Hydrocad model prepared by WBRC predicted the following peak flow rates for the stream for existing conditions.

TABLE 2.1 – FLOW AMOUNTS AT STATIONS (EXISTING CONDITIONS)

STATION	PEAK FLOW (1-YEAR, CFS)	PEAK FLOW (2-YEAR, CFS)	DESCRIPTION
0+000	270.44	324.78	Mouth of Stream
0+950	270.56	321.46	Tributary #3 confluence.
3+700	247.29	291.64	Meadow Brook confluence
5+400	223.77	265.17	Hogan Road crossing
7+250	194.52	228.02	I-95 crossing
8+900	77.23	92.87	Bangor Mall Blvd crossing
10+000	54.84	66.43	Stillwater Ave crossing
12+500	7.00[5]	7.00[5]	Headwater (assigned)

[5] Since the observed base flow represents a steady-state condition, it retained its value for 1- and 2-year storms.



The table and graph above illustrate the significant (40%) contribution in peak flow from the developed area between Bangor Mall Boulevard and Interstate 95.

2.4 – Relationship to Imperviousness:

Stream condition has generally been shown to directly relate to a variable known as "imperviousness", defined as all roads, parking lots, sidewalks, roofs, and any other areas that are not "green".[6] Generally, stream degradation occurs at or near a level of 10% total watershed imperviousness. The Penjajawoc Watershed currently has a watershed imperviousness of 8%.[7]

An impervious area generally contributes runoff in greater amounts than does a pervious one. As shown in table 2.3, it was found that subareas with high ratios of runoff to acreage were areas that had a high percentage of impervious coverage and insufficient BMPs. Areas with effective BMPs and/or natural coverage conditions had lower ratios. See Appendix B for Hydrocad routing diagram and figure A-3 Subwatershed Identification in Appendix A. See also figure A-2 for stream station identification.

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6 Schueler & Holland
7 Parish Geomorphic

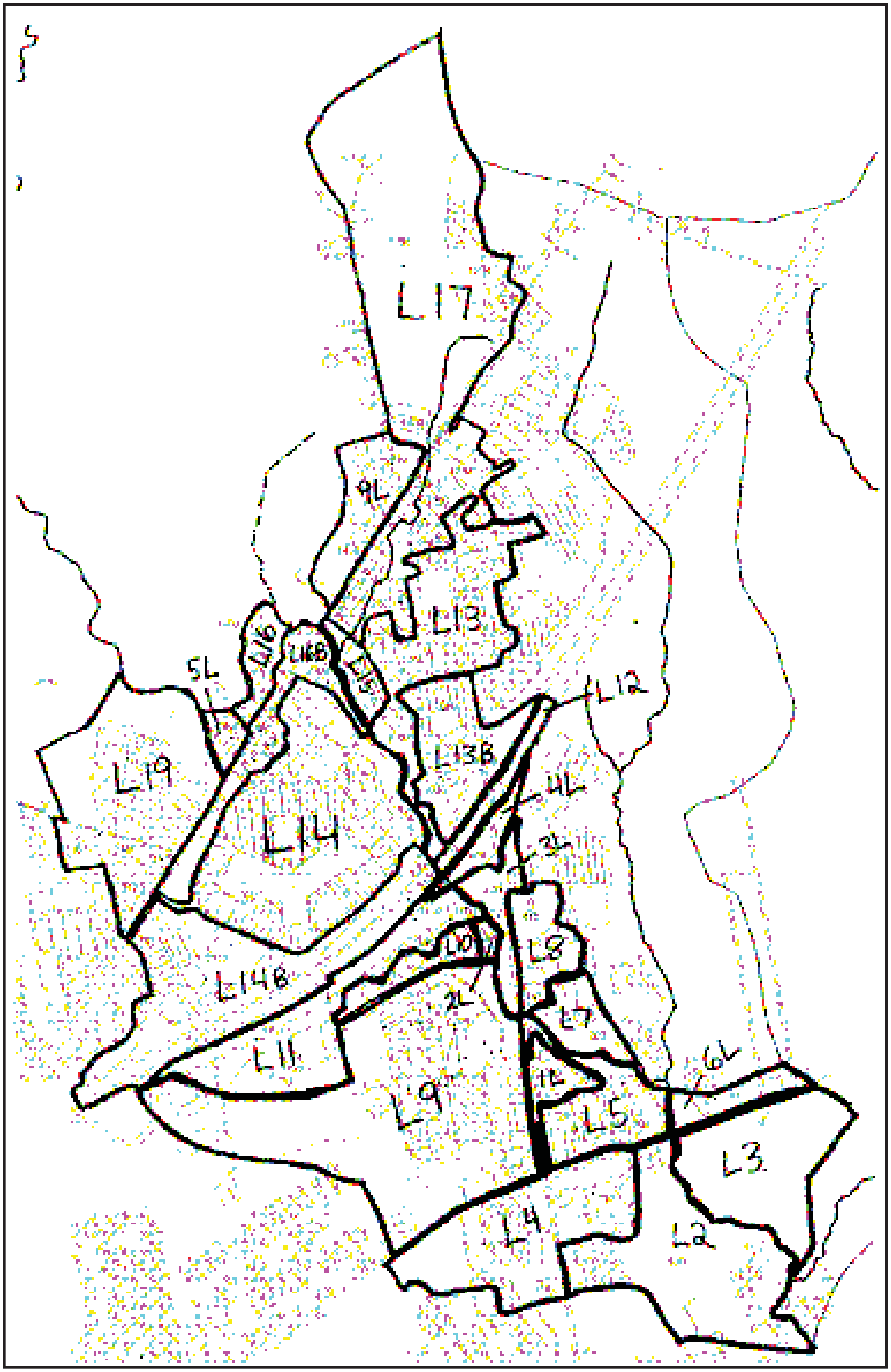
TABLE 2.3 – SUBAREA OUTFLOW PER ACRE, 2-YEAR STORM EVENT (EXISTING CONDITIONS)

Stream Station	Link[8] Number	Inflow Area (acres)	Outflow Peak (cfs)	Percent imper-vious[9]	Peak CFS per acre	Subareas included in link
1+969	L2	49.92	8.03	12%	0.161	100
2+369	L3	38.22	9.25	1%	0.242	10
3+165	L4	43.62	20.50	40%	0.470	110, 520
3+165	6L	8.36	3.64	13%	0.435	11
3+838	L5	21.48	20.94	53%	0.975	310, 300
4+809	1L	6.25	13.07	86%	2.092	322, 320, 311, 321
4+809	L7	10.23	7.09	27%	0.693	200
5+246	L8	13.67	22.74	65%	1.664	412, 410, 411
5+400	L9	115.03	17.07	20%	0.148	500
6+222	2L	1.50	1.86	12%	1.242	1300
6+222	L10	10.18	12.14	84%	1.192	500
6+566	3L	8.69	10.78	29%	1.240	400
6+566	L11	35.31	14.85	27%	0.421	1700, 1500, 1710, 1711, 1712
7+005	4L	6.28	6.62	32%	1.053	600, 1900
7+420	L12	6.50	3.78	31%	0.582	800
7+420	L14B	60.46	31.82	31%	0.526	2100, 2300, 2514, 2510, 2512, 2513, 2511
7+420	L13B	25.54	8.89	51%	0.348	1010, 1030, 1040
8+188	L13	42.47	83.15	66%	1.958	1000, 1220,1090, 1091, 1092, 1093, 1094
8+188	L14	75.37	53.08	41%	0.704	2550, 2500
8+919	L15	6.52	10.57	47%	1.622	1200, 1210
9+832	L17	128.44	40.48	20%	0.315	1240, 1270, 1230, 1280, 1290, 1291, 1297, 1298, 1292, 1299, 1420, 1296, 1293, 1294
10+111	L16B	18.18	20.35	38%	1.119	2910, 2710, 2700, 2720, 2730, 2740, 2750
10+111	9L	18.08	16.48	38%	0.912	1410B, 1410, 1412, 1413
10+888	L16	7.97	9.22	45%	1.156	2900
12+121	5L	4.52	8.01	49%	1.773	2920
12+121	L19	56.07	38.94	47%	0.695	3110, 3160, 3150, 3140, 3130, 3120

As expected, the peak runoff expressed in a "peak-per-acre" comparison is highest in subareas with higher imperviousness and without retention BMPs. This is important when reviewing BMP selection since, in some subareas, detention may still provide more benefit to the stream quality through peak flow reduction than other methods of runoff control, at or below a 2-year design discharge.

8 A "link" is an element within Hydrocad that signifies an entry point into the hydrologic model. In this case, a link represents a summary discharge for a group of subareas into the stream model. See figure 2.0.
9 "Percent Impervious" was calculated by analyzing the ratios of buildings and pavement to grassed areas within the defined tributary area. It des not reflect the percent coverage for any given parcel within.

FIGURE 2.0 LINKED DRAINAGE AREAS



2.5 – Existing BMPs:

Approximately twenty-five (25) existing retention Best Management Practices were observed and included in the hydrologic models to determine their effect on peak flow contribution. As these BMPs were built before a November 2005 update in Chapter 500 stormwater regulations, most do not comply with current quality standards.[10] Methods of existing stormwater management observed include detention ponds, level spreaders, bioretention areas, and prefabricated products. (Table 2.4)

<u>TABLE 2.4 – BMPS OBSERVED IN WATERSHED AFFECTING PEAK FLOW RATE</u>

BMP #	W.S. #	Comment	Approx. Year Installed
1	5151	Target-Home Depot pond	1997
2	1292	Target level spreader	2004
3	1292	Ski Rack pond	1992
4	3120	Pond Avenue	not yet?
5	3120	3x Stormtreat	not yet?
6	3110	Pond Widewaters	not yet
7	3110	Bioretention areas (multiple)	not yet
8	2511	Cinema pond	1990
9	310	Quirk large pond	1998
10	320	Quirk small pond	2001
11	500	Pond EMCC[10]	2006
12	1410	Crossroads pond south	1994
13	1412	Crossroads pond north	1994
14	1420	Retail pond	2001
15	1294	Ridgewood pond	1995
16	2550	Mall pond	1998
17	1091	Van Syckle pond	2001
18	1030	Toys R Us pond	1977
19	500	2x ponds Darling's	2004, 1987
20	200	Level spreader BFCU	1993
	OMITTED:		REASON:
	Crossroads uppermost pond		No development inflow
	Petco Stormtreat systems		Qin=Qout
	Second BFCU level spreader		Affected Tc, short distance
	Detention pond in WS 1280		Qin=Qout

[10] One exception is found within BMPs created to address an 80% TSS reduction, which have been found to readily lend themselves to retrofit to the new treatment volume requirements without losing their value to control 2-, 10-, and 25-year peak events.

3.0 – Summary of Recommendations:

Due to the relatively sensitive nature of the Hydrocad hydrology model to certain BMP modifications or additions, it is important that all BMP pond retrofits affecting stormwater discharge into the stream be updated within this model. We strongly encourage the creation of a watershed coordinator position. This individual or firm should be responsible for ensuring that the hydrologic model is properly updated for any development occurring within the Penjajawoc Watershed.

Due to the complexities of land coverage, marsh storage effects, beaver dam activity, and large wooded areas the upper Penjajawoc watershed, Meadow Brook tributary and Tributary #3 were not modeled as Hydrocad subareas and were instead each input as an assigned 2-year base flow value. These values were obtained from the companion reports, which are not based on actual logged stream flow values. It is recommended that stream flow gauging be conducted on a regular basis at the three points identified above to provide accurate base flow data for the hydrologic model.

As a result of the hydrologic model's predictions for 1- and 2-year storm events and the observations within the SWMM and geomorphic analysis, four BMPs were identified:

1a. K-Mart #1 – Install in-system storage facility to attenuate and treat surface runoff from KMART roof and parking area that currently discharges directly to the stream. (Goal – Reduce frequency of damaging 2-year peak flow event, treat runoff prior to discharge, improve base flow condition, improve thermal conditions.)

1b. K-Mart #2 – Install underdrained vegetated swales along existing grassed area to treat runoff from paved areas. (Goal – Treat direct runoff, promote stream base flow conditions, improve thermal conditions).

2a. Bangor Mall #1 – As a result of table 4.2 results, modify the existing Bangor Mall detention basin outlets to attenuate a 1-year storm event, decrease the discharge during a 2-year storm event, and permit a slightly higher discharge during 10- and 25-year events for a 66-acre contributing impervious area. (Goal – Reduce frequency of damaging 2-year peak flow events.)

2b. Bangor Mall #2 – Modify the inflow entering the Bangor Mall detention basins to permit bypass of low flow, cool, clear underdrain discharges to enter the stream directly, instead of mixing with the warmer runoff contained in the wet pond for a 66-acre contributing impervious area. (Goal – Promote or restore stream base flow conditions, improve thermal conditions).

3. MDOT #1 – Install underdrained grass swales (bioretention swales) within the invert of the existing I-95 drainage swales to reduce frequency of damaging 2-year peak flow events, filter runoff through underdrain soil media, and promote stream base flow and

improved thermal conditions for approximately 20 acres of contributing impervious area. (Goal – Treat direct runoff, promote or restore stream base flow conditions, improve thermal conditions).

4. EMCC #1 – Modify the existing EMCC detention basin by modifying the existing outlet structure weir to detain a 1-year runoff and installing a new small diameter outlet to drain off the storage over an extended period, and cooling the discharge with an extended buried pipe run prior to discharge into the stream for a 15.5-acre contributing impervious area. (Goal – Reduce frequency of damaging 2-year peak flow events, promote or restore stream base flow conditions, improve thermal conditions).

Zoning Recommendations

Grandfathered private landowners need incentives to properly retrofit their stormwater systems. One suggestion would be to allow more development with the caveat that some funds would go toward mitigation. This tactic has been successfully implemented in many municipalities.

The concept of watershed-based zoning is one in which, in order to minimize the creation of additional impervious area at the regional scale, development is concentrated in high-density clusters. Again, we recommend the creation of a watershed manager position. This would enable a "whole-watershed" approach to future development and would enable information to be compiled in a practical and accessible way.

4.0 – BMP Retrofit Designs

4.1 – BMP/LID Improvements Matrix:

The Maine DEP has developed a design manual to assist in selecting and developing appropriate Best Management Practices for development in Maine. Included with the DEP's publication is a selection matrix to aid selection of different types of BMPs. This matrix was used as a starting point in this report and expanded to specifically include the Penjajawoc subwatersheds, and to indicate which BMPs would be appropriate for retrofit or new installation where required. See table 4.0 – BMP Retrofit Matrix, included at the end of this section.

4.2 – Basic Approaches to Retrofit:

Three basic approaches to retrofit existing BMPs were identified:

- ☐ Construct new Low Impact Development infiltration swales to filter, attenuate, and cool runoff that currently discharges directly.
- ☐ Modify existing wet ponds to promote infiltration and base flow, while cooling runoff prior to discharge to the stream.
- ☐ Intercept underdrain runoff prior to entering ponds to promote base flow.

4.3 – BMP Retrofit Sites:

Four areas were outlined as possible areas of BMP retrofit improvements. See figure A-4 Proposed BMP Retrofit Subareas in Appendix A for locations of BMP tributary watersheds. The four (4) BMPs or sites were chosen to obtain the maximum benefit for investment, and to address the stated project goals. It just so happens that the BMPs occur in land controlled by a diverse group of stakeholders including the state, city, and private landowners.

1. <u>K-Mart Vicinity:</u>
   The area surrounding K-Mart and Best Buy is a large 35-acre developed area containing virtually no BMPs. The area constitutes development predating current stormwater regulations, so most runoff directly enters the stream untreated by way of a piped stormwater system. With 26.8 acres being impervious, this area represents 0.6% of the total watershed and 4.3% of the developed middle reach section. Several stakeholders have expressed the desire for this area to obtain retrofit BMPs. Included are subwatersheds 1220, 1090, 1092, 1093, and 1094. (See figure A-3 in Appendix A.)

2. Bangor Mall Vicinity:
   The Bangor Mall stormwater system dates to the late 1970s and was refitted in 1998 to the sliding scale TSS removal standard. However, the regulations have since been updated. This 66-acre development represents 1.1% of the total watershed and 7.5% of the developed section.

3. I-95 Vicinity:
   Interstate 95 contributes approximately 20 acres of impervious area to the modeled watershed. It contains no formal BMPs and is likely a contributor of non-point source contaminants due to vehicle traffic. The total proposed BMP area is 15.8 acres, which is 0.3% of the total watershed, and 2% of the middle reaches. It should be noted that additional lengths of Interstate 95 flow through the watersheds of the Penjajawoc's tributaries, but these were considered out of the study area and only the 20 acres flowing directly to the Penjajawoc Stream were considered. This area contains some or all of subwatersheds 600, 1010, 1710, 2300, 2514, and 2510.

4. EMCC Campus:
   Eastern Maine Community College recently constructed a wet pond to treat runoff to 80% TSS removals. Due to stormwater rule changes, the new system is already obsolete. As it is located in an urban impaired watershed, the College is required to have adequate facilities for its runoff. 55 acres contribute to the existing detention pond, 15.5 of which are impervious, representing 0.97% of the total watershed and 6.7% of the middle reach section.

These retrofit areas will collectively affect 172 acres. This amounts to 3% of the total watershed and 21% of the middle reach section.

4.4 – Four Proposed New or Retrofit BMPs:

4.4.1 – K-Mart Location:

K-Mart and the surrounding area including Best Buy, Applebee's, and several strip malls, currently contributes an estimated 71 cfs to the stream during a 1-year storm. This runoff enters the stream at the middle reaches just upstream of the Bangor Mall outlet.

Suggested Retrofit:

1. Install flow-splitters and two (2) in-system underground storage structure(s) to attenuate 1- and 2-year frequency runoff from roof and parking areas that currently discharge directly to the stream.

2. Add an underdrained open swale along existing grass area along Hogan Road and K-Mart parking lot; readjust size of existing service road as needed.

Retrofit Purpose:

- Improve thermal conditions,
- Improve base flow condition; and
- Reduce frequency of damaging 1- and 2-year peak flow events.

Analysis:

Unless a significant reconstruction occurred and re-oriented the entire parking layout with horizontally placed underdrained bioretention swales, it was determined that LID retrofit systems would be ineffective in capturing surface runoff and that structural BMPs and/or proprietary systems would be more viable when tied into existing storm systems.[11] A leading proprietary stormwater system supplier indicated that proper treatment of stormwater from this site would require large numbers of pretreatment and treatment structures and would therefore be prohibitively expensive. It was therefore determined that peak flow attenuation should be the method explored as the large peak flows from the site are likely damaging the stream channel.

Sizing for the tanks was calculated by using the channel protection volume (1" runoff from paved areas) multiplied by the 23 acres impervious contributing area from subareas 1091, 1092, and part of 1093. This resulted in a need for approximately 2 acre-feet of storage.

23 acres*43560 SF per acre*1"/12*0.95= 79,316 CF <- Greater value
(23 acres*43560 SF per acre*1"/12 + 2 acres*43560 SF per acre*0.4"/12)*0.80= 69,115 CF

The City of Bangor has in the past installed pre-cast concrete structures to attenuate the city's combined sewer overflows. These structures proved to be very cost-effective, having been relatively inexpensive to design and install and successful at serving their purpose. It was therefore proposed to install a similar structure underneath the parking lot of K-Mart. Two (2) 10' high by 8' wide by 500' long sections of pre-cast concrete chambers would store up to 600,000 gallons.

The flow splitters were modeled to direct 100% of the 1-year frequency event into the storage tanks, with any exceeding event bypassing the tanks and discharging into the downstream piped system. The nearly 2 acre-feet of storage provided in

[11] The MDEP will allow structural BMPs on a case-by-case basis.

these tanks results in nearly ten hours of extended detention, and a flow reduction of nearly 93% compared to existing conditions.

Sufficient grade change exists within this storm system (in excess of twenty feet) to permit the adequate burial of the ten-foot tall tank system. K-Mart's parking lot is at elevation 120' NGVD. The bottom of the tank should be at or near elevation 98' and thus the top will reach elevation 108'. This leaves approximately 10 feet of grade remaining to install any catch basins, underground utilities, gravel subbase, etc.

The flow splitter was modeled as follows:

- (1) Primary outlet culvert, 24" diameter, invert elevation 97.0
- (1) Secondary outlet culvert, 48" diameter, invert elevation 99.0

The tank outlet was modeled as follows:

- (1) 6.5" orifice in concrete wall at elevation 98';
- (1) sharp-crested weir (top wall) at elevation 107.46'

The tank system attributes were selected by examining several different combinations of tanks and outlets. The best overall combination was then selected as the chosen design. All outlet devices drain into an existing 48" diameter storm drain pipe.

TABLE 4.1 IN-SYSTEM TANK OPTIONS

Predevelopment (CFS)	~10	
Current (no BMPs)	47.68	
All flows into tank	Outlets 1x	Outlets 2x
Pond 1x	37.53	33.05
Pond 2x	12.57	9.24*
Flow Splitters	Outlets 1x	Outlets 2x
Pond 1x	31.16	25.59
Pond 2x	23.88	24.90

This BMP may require the installation of additional stormwater pipe into the existing system in order to convey runoff into the tank.

The south side of the K-Mart parking lot, as well as the side abutting Hogan Road, contains a strip of grassed area. It has been proposed to retrofit this grassed area with underdrained vegetated soil filters to collect and treat runoff from

Hogan Road and from the parking lot. This system would tie into the existing storm drain system on site.

4.4.2 – Bangor Mall Pond Outlet:

The Bangor Mall detention Basins were constructed in 1977-1978 during the original Mall construction and later modified in 1998 during a major renovation project. The original 1977 hydrologic analysis, conducted by Raymond Keyes Engineers, targeted a 50-year storm event. Sediment buildup over twenty years and failure of the pond primary outlet structure (piping and washout of outlet culvert piping and bedding) prompted remedial activity in 1998. The repair consisted of replacement of the primary outlet pipe, installation of anti-seep collars, raising the berm height to accommodate a 100-year storm event, and restoring wet pond volume by removing built-up sediment from both wet ponds. Additional armoring (articulating concrete mats) was installed at several weir locations in the pond.

The Bangor Mall system is engineered in such a way so that very cold (~50 degree) groundwater is exiting the system into the detention pond continuously at a minimum rate of 25 gallons per minute. This groundwater would be beneficial to the stream if it were to enter directly.

Suggested Retrofit:

To modify the existing stormwater detention pond, the suggested BMP retrofit at this structure consists of the following:

1. As a result of table 4.2 results, modify the existing detention basin outlets from 24” to 18” culverts to attenuate a 1-year storm event, decrease the discharge during a 2-year storm event, and permit a slightly higher discharge during 10- and 25-year events.

2. Modify the inflow entering the detention basins to permit bypass of low flow, cool, clear underdrain discharges to enter the stream directly, instead of mixing with the warmer runoff contained in the wet pond.

Retrofit Purpose:

- ☐ Treat runoff prior to discharge, improve base flow condition;
- ☐ Improve thermal conditions; and
- ☐ Reduce frequency of damaging 2-year peak flow event.

Analysis:

Reduction of the Bangor Mall pond outlet culvert from 24" to 18" diameter appears to result in a 35% reduction in flow out of the pond during a 1-year event; however, total flow at the discharge point in the stream is projected to decrease by about 9%. It should also be noted that if the pond outlet culverts were reduced to two (2) 18" openings, the discharges for 1- and 2-year storm events would decrease but any larger (10- and 25-year) storm event would see an increase in discharge. As research has shown, this may not be damaging to the stream.

Reduction of the outlet culverts to diameters of 15" or 12" was not feasible because of excessive weir overtopping. Raising the overflow weir to maintain control during 10- and 25-year events resulted in pond storage elevations peaking at levels higher than is commonly acceptable in current engineering practice. Raising the berm height to accommodate additional storage was not feasible due to space and budgetary constraints.

Results of this suggested modification during peak flow events are shown in the following table:

TABLE 4.2 – BANGOR MALL POND OUTLET RETROFIT

81.85' top of berm				
79.85' weir invert	1-YEAR	2-YEAR	10-YEAR	25-YEAR
existing inflow:	112.10	128.91	207.21	243.00
existing:				
2X 24" CULVERTS	77.91'	78.40'	80.14'	80.25'
combined outflow	47.47	52.00	121.01	172.31
primary	47.47	52.00	65.44	66.28
secondary	0.00	0.00	51.89	106.03
try:				
2X 18" CULVERTS	78.69'	79.28'	80.25'	80.31'
combined outflow	31.77	34.38	144.35	200.91
primary	31.77	34.38	38.24	38.46
secondary	0.00	0.00	106.11	162.45
try:				
2X 15" CULVERTS	79.16'	79.79'	80.28'	80.37'
combined outflow	23.89	25.66	169.62	254.68
primary	23.89	25.66	26.96	27.21
secondary	0.00	0.00	142.61	227.47
try:				
2X 12" CULVERTS	79.71'	80.07'	80.34'	80.40'
combined outflow	16.33	42.04	199.16	266.90
primary	16.33	16.93	17.33	17.47
secondary	0.00	25.11	181.78	249.42

Note: primary outflow is two (2) culverts; secondary outflow is a broad-crested overflow weir.

The main outflow outlet for the Bangor Mall storm/underdrain system is a 54" diameter corrugated pipe. It emits a constant outflow of groundwater. This flow rate was measured at 25 gallons per minute in August 2006. Cold groundwater base flow would be beneficial to the Penjajawoc Stream. It has therefore been proposed to retrofit this outflow pipe with a device that would reroute the groundwater but continue to pass any storm events into the retention basin. One proposed method would be to install a basket full of riprap at the outlet of the 54" pipe. This basket would be removable for easy cleaning and would have a drain at the bottom to bypass the groundwater directly into the stream instead of into the retention pond. The proposed outlet pipe would be 4" to 6" in diameter, which would facilitate passage of low flows but would force any larger flows into the wet pond.

4.4.3 – Interstate 95:

Interstate 95 contributes 20 acres of impervious surface to the Penjajawoc Stream, directly. In order to filter the runoff, underdrained vegetated soil filters with stone check dams have been proposed.

Suggested Retrofit:

1. Install stone-check/underdrained ditches within the invert of the existing drainage swales to treat runoff prior to entering the stream and to reduce frequency of damaging 1-year peak flow events.

Retrofit Purpose:

- Treat direct runoff;
- Promote or restore stream base flow conditions; and
- Improve thermal conditions.

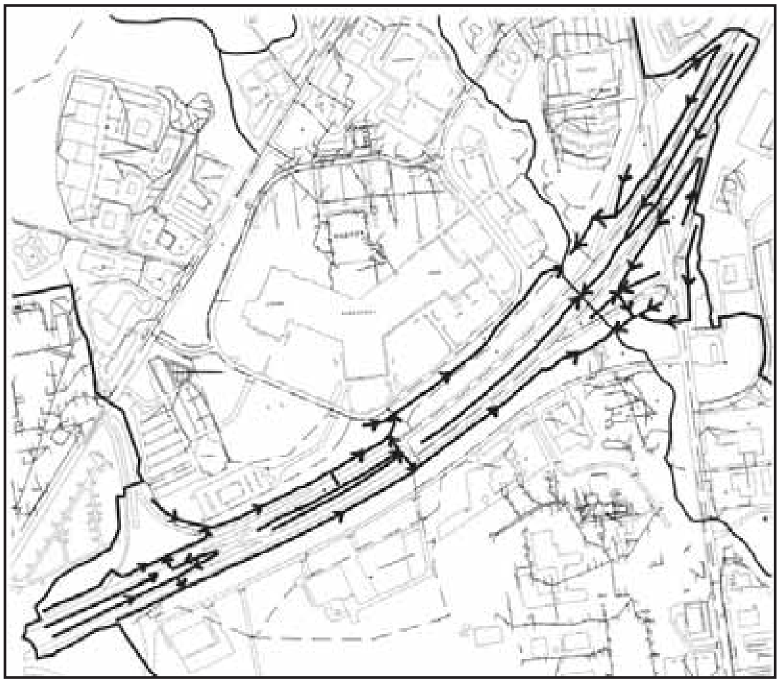
Existing and proposed outflow comparisons were not available for this site because the stormwater enters the stream at several different points.

Analysis:

It should be noted that the proposed BMP for this site is an innovation in BMP technology. It combines underdrained soil filter technology with check dams to produce a BMP with traits from both types of original BMPs.

The following is an image of some prominent flow paths taken by runoff from the Interstate. These were gauged by inspection of aerial photography and as-built plans provided by Maine Department of Transportation, dated 1978.

FIGURE 4.0 FLOW PATHS FROM INTERSTATE RUNOFF



The following is a table of treatment volumes required for the freeway subcatchments.

TABLE 4.3 BMP NEEDS OF FREEWAY SUBAREAS

WS	LF	SL	95% imp	80% all	Treatment vol. CF	Dams needed
600	1,500	3%	2,969	3,900	3,900	18
1010	2,000	3%	3,958	5,200	5,200	24
2514	4,000	2%	7,917	10,400	10,400	31
1710	4,000	2%	7,917	10,400	10,400	31

The stone check dams should be 18" high and retain an average of 9" of water. An infiltration rate of 0.08 cfs was assumed; this is a standard number for must infiltration BMPs. The filters must drain in 36 hours or less. The length of the impoundment varies with local slope. Areas with a 3% slope receive impoundment lengths that are 50 feet in length. Areas with a 2% slope receive impoundment lengths of 75 feet.

It was determined that the entire necessary length to treat the northern watersheds would be difficult to fit into the space available. It was therefore determined that stone-check/underdrained soil filters should be placed wherever possible along the existing drainage swales. An impermeable liner would not be necessary.

Treatment volume is defined as 1" times the impervious area plus 0.4" times the grassed area of a subcatchment. 95% of impervious area or 80% of all area must be included for treatment, whichever results in a greater treatment volume. It was assumed that each swale would be treating half the width of the roadway plus the shoulder of the roadway. The roadway is 50 feet wide, so on average each swale would be treating 25 feet of paved area per linear foot of roadway. The shoulder width was estimated to be 35 feet per linear foot of roadway.

Treatment volume for typical 50'-long roadway section:
25'*50'*(1"/12)*0.95=99 CF
(25'*50'*(1"/12)+35'*50'*(0.4"/12))*0.80=130 CF <- Greater value

<u>4.4.4 – Eastern Maine Community College:</u>

The EMCC detention basins were constructed in 2004 to attenuate the runoff from post-1975 development and included capacity to attenuate runoff from more than two acres of future impervious development. The pond includes a permanent wet pond with storage above, and resulted in a weighted treatment for all Campus runoff of 80% TSS. The stormwater management rules were revised shortly after the construction of the wet pond.

Suggested Retrofit:

To modify the existing stormwater detention pond, the suggested BMP retrofit at this structure consists of the following:

1. Install a 6" storm drain with gate valve in the stormwater detention pond at invert elevation 85.35' so that the permanent wet pool elevation will be lowered from 87.35' to 85.35'. The outlet of the 6" storm drain will be connected to approximately 100' (171.5' effective length) of buried flexible corrugated perforated pipe (e.g. Hancor heavy duty pipe) to cool runoff before discharge into the stream.

2. Modify an existing control structure plate to attenuate below the 2-year event to a 1-year event:
- ☐ Cover the three 5" orifices at elevation 87.35';
- ☐ Narrow the length of the sharp-crested weir at elevation 88.35' from 4' to 2'; and
- ☐ Increase the rise of the sharp-crested weir from elevation 89.35' to elevation 91.55'.

Retrofit purpose:

All requirements for the college's stormwater effluent will be met with these improvements, resulting in a reduction of the 1-year peak flow from 13.53 cfs to 10.25 cfs.

Attenuating 90% of all storm events (1-year) and cooling the relatively warm wet pond will promote increased stream base flow and permit channel stabilization.

TABLE 4.4 EXISTING AND PROPOSED SUBAREA OUTFLOWS (CFS)

(CFS)	1-YEAR	2-YEAR	10-YEAR	25-YEAR	100-YEAR	500-YEAR
existing inflow:	31.67	37.64	67.06	80.79	98.08	111.42
Existing pond total outflow	6.71	7.70	22.09	29.17	49.72	75.99
Proposed pond total outflow	5.42	7.90	20.32	26.87	35.29	55.37
Total outflow existing conditions	13.53	17.06	45.03	65.54	103.93	148.86
Total outflow proposed conditions	10.25	13.96	48.13	66.62	92.05	135.61

This retrofit results in a 20% decrease in pond outflow for a 1-year storm, and a 25% overall site decrease.

Analysis:

We are proposing to modify the stormwater detention pond to accommodate all of the post-1975 development that is located within the stormwater detention pond tributary area according to the revised DEP stormwater management rules.

TABLE 4.5 IMPERVIOUS AND DEVELOPED AREAS IN THE STORMWATER DETENTION BASIN TRIBUTARY AREA ON THE EMCC CAMPUS (SF)

Sub-catchment	Pre-1975 (SF)			Post-1975 (SF)			Total (SF)
	Grass	Impervious	Woods	Grass	Impervious	Woods	
202	33,852	22,513	82,531	53,241	85,651		138,895
402	9,941		59,878	37,675	29,122	3,022	69,820
403	81,239	38,307	6,420	105,311	20,300	355	125,966
405	33,010		105,181	20,016	118,175		138,192
406	105,345		14,867	41,179	79,032		120,211
501	38,806	7,540	68,579	86,337	28,587		114,925
502	20,610	8,007	89,698	66,984	51,331		118,315
601	66,020	40,731	8,232	78,448	28,749	7,785	114,982
602	113,331	17,505	8,368	18,578	14,327	106,299	139,204
802	14,629	43,023	35,953	37,585	56,020		93,605
902	45,258	32,498	12,568	15,327	74,998		90,325
701A	16,005	66,800	10,147	412	92,540		92,952
Total (SF)	578,045	276,924	502,422	561,094	678,832	117,461	1,357,391
Total (acres)	13.27	6.36	11.53	12.88	15.58	2.70	31.16

Due to the pond's situation on a hillside slope, and due to the presence of adjacent stream and wetland vegetation, it is not feasible to further excavate the pond to provide room for a new underdrained filter bench around the perimeter of the pond.

Calculations:

a. Minimum Permanent Pool Volume

According to the revised DEP stormwater management rules, the minimum permanent pool volume equals 1.5" times the impervious area plus 0.6" times the non-impervious developed area:

1.5" x (401,908 SF + 49,132 SF) + 0.6" x 0 SF

Minimum Permanent Pool Volume = 56,380 CF

b. Minimum Channel Protection Volume

According to the revised DEP stormwater management rules, the minimum channel protection volume equals 1.0" times the impervious area plus 0.4" times the non-impervious developed area:

1.0" x (401,908 SF + 49,132 SF) + 0.4" x 0 SF

Minimum Channel Protection Volume = 37,587 CF

c. Existing Stormwater Detention Pond

Elevation at bottom of pond: 86.0’[12]
Elevation of permanent pool: 97.0’
Elevation at top of berm: 104.0’

TABLE 4.6 EMCC STORMWATER DETENTION POND STORAGE VOLUME

Elevation (ft)	Surface (SF)	Storage (CF)
86.0	5,028	0
88.0	7,790	12,718
90.0	10,392	30,837
92.0	13,274	54,445
94.0	16,436	84,098
96.0	20,018	123,919
98.0	23,600	163,740
100.0	27,602	214,889
102.0	31,884	274,324
104.0	36,345	342,504

d. Proposed Stormwater Detention Pond Modifications

Install a 6" storm drain with gate valve in the stormwater detention pond at invert elevation 95.0’ so that the permanent pool elevation will be lowered from 97.0’ to 95.0’.

Permanent pool volume @ 95.0' = 104,009 CF > 56,380 CF -> OK

Provide the following modifications to the existing control structure plate:

- Cover the three 5” orifices at elevation = 97.0’;
- Narrow the length of the sharp-crested weir at elevation 98.0’ from 4’ to 2’; and
- Increase the rise of the sharp-crested weir from elevation 99.0’ to elevation 101.2.

Channel protection volume (95.0' to 98.0') = 59,731 CF > 37,587 CF -> OK

e. Minimum Treatment Percentage

Stormwater runoff from at least 95% of new impervious area must be treated:

- Post-1975 impervious area (detention pond): 401,908 SF
- Entrance drive impervious area (no treatment): 21,578 SF

[12] Bangor City Datum

- ☐ Impervious area treatment percentage:

(401,908 SF / 423,486 SF) x 100 = 95% -> OK

Stormwater runoff from at least 80% of new non-impervious developed area must be treated:

- ☐ Post-1975 developed area (detention pond): 401,908 SF
- ☐ Entrance drive developed area (no treatment): 38,178 SF
- ☐ Developed area treatment percentage:

(401,908 SF / 440,086 SF) x 100 = 91% > 80% -> OK

f. Urban Impaired Stream Standard

As the EMCC campus is located in an Urban Impaired Stream watershed, the Urban Impaired Stream Standard applies to the site. We are proposing to treat a high use pre-development on-site parking lot to address this standard

Permitted Impervious Area (2001)

a. Buildings: 158,743 SF (3.64 acres)
b. Travelways: 481,589 SF (11.06 acres)

Proposed Master Plan

a. Buildings: 234,393 SF (5.38 acres)
b. Travelways: 538,553 SF (12.36 acres)

Required Credit

a. Roof: (0.2/acre) x (5.38 acres - 3.64 acres) = 0.348
b. Non-roof impervious area: (0.5/acre) x 12.36 acres – 11.06 acres) = 0.65
c. Total required credit: 0.998

Mitigation Credit

Treat pre-1975 high use parking lot with wet pond BMP (1.5/acre)

Parking lot behind Maine Hall: 49,132 SF

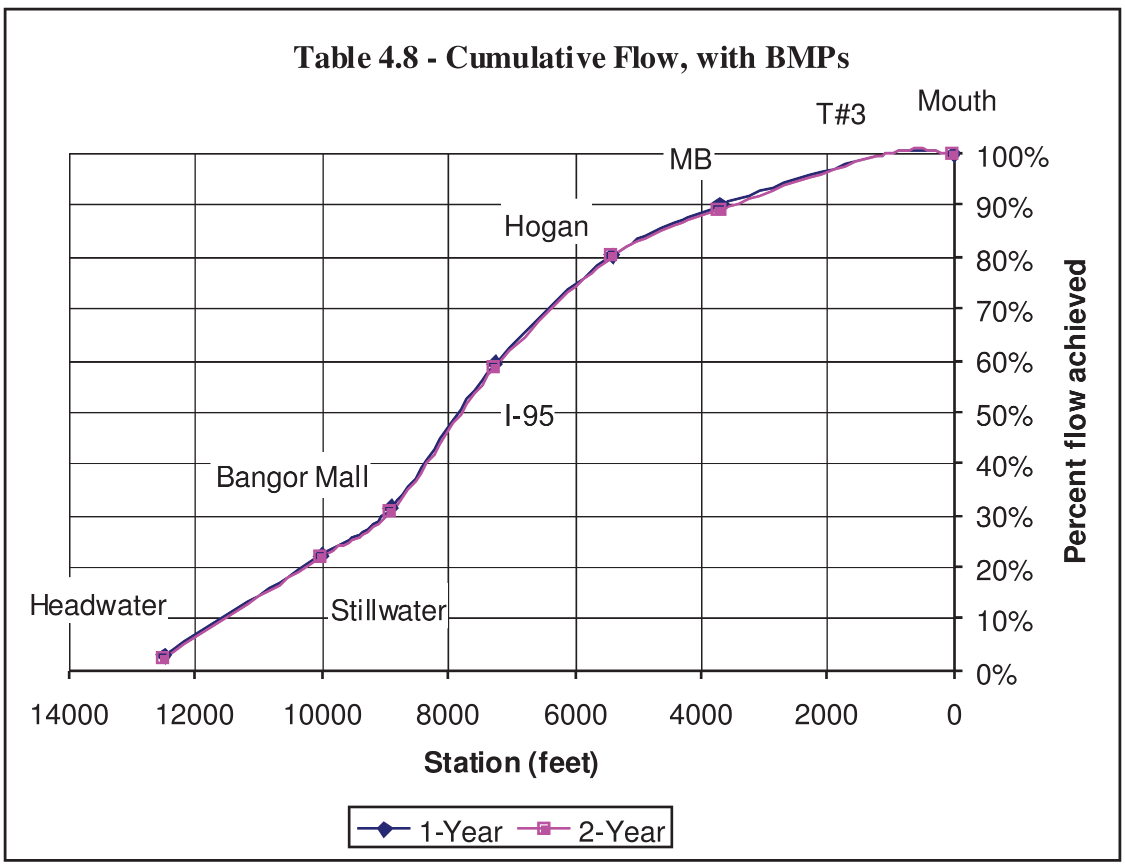
1.13 acres x 1.5/acre = 1.69 > 0.998 -> OK

4.5 – Results of Hydrologic Model after Recommended BMP Changes:

After insertion of all four proposed BMPs, the hydrologic model was re-calibrated. The model gave the following resulting peak flows:

TABLE 4.7 – FLOW AMOUNTS AT STATIONS (PROPOSED CONDITIONS)

STATION	PEAK FLOW (1-YEAR, CFS)	PEAK FLOW (2-YEAR, CFS)	DESCRIPTION
0+000	245.91	302.41	Mouth of Stream
0+950	246.43	303.07	Tributary #3 confluence.
3+700	221.16	269.41	Meadow Brook confluence
5+400	197.34	241.78	Hogan Road crossing
7+250	145.94	176.91	I-95 crossing
8+900	77.23	92.87	Bangor Mall Blvd crossing
10+000	54.84	66.45	Stillwater Ave crossing
12+500	7.00	7.00	Headwater (assigned)



4.6 – Zoning Change Recommendations:

Grandfathered private landowners need incentives to properly retrofit their stormwater systems. One suggestion would be to allow more development with the caveat that some funds would go toward mitigation. This tactic has been successfully implemented in many municipalities.

The concept of watershed-based zoning is one in which, in order to minimize the creation of additional impervious area at the regional scale, development is concentrated in high-density clusters. As Schueler and Holland state in their report - "The Importance of Imperviousness", "Watershed-based zoning should provide managers with greater confidence that resource protection objectives can be met in future development. It also forces local governments to make hard choices about which streams will be fully protected and which will become at least partially degraded. Some environmentalists and regulators will be justifiably concerned about the streams whose quality is explicitly sacrificed under this scheme. However, the explicit stream quality decisions which are at the heart of watershed-based zoning are preferable to the uninformed and random 'non-decisions' that are made every day under the present zoning system."

Again, we recommend the creation of a watershed manager position. This would enable a "whole-watershed" approach to future development and would enable information to be compiled in a practical and accessible way.

A main goal of modern zoning theory is the reduction of a phenomenon commonly referred to as urban sprawl. This occurs when development is spread over large swaths of area, often unnecessarily. To prevent this phenomenon from occurring in the Penjajawoc Watershed, it has been proposed to offer incentives to landowners.

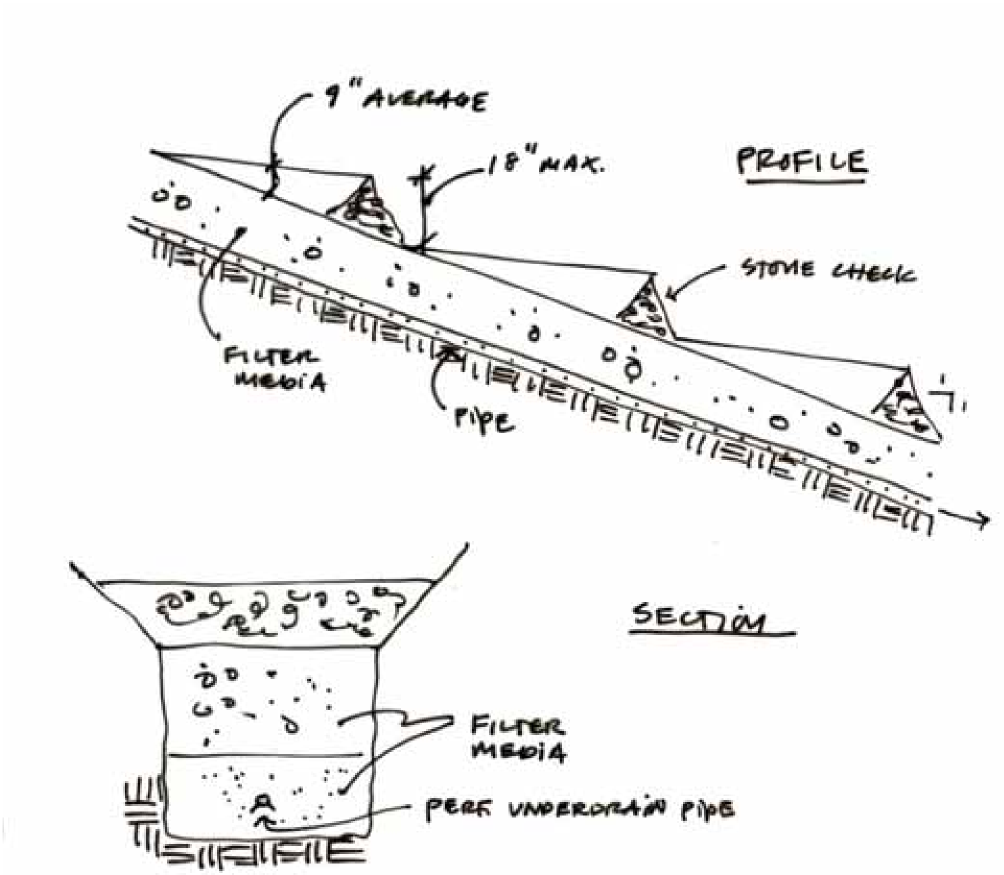
Lot coverage in much of the area in question is currently at 70% due to local ordinances. If landowners were allowed to exceed that coverage, they may be enticed to offer compensation. For example, for every 1% they go above 70%, they would offer a set amount of mitigation money, 10% of the lot value for example, towards stream restoration. All stormwater runoff quality and quantity thresholds would still need to be met. This would allow more development in less space. Landowners would likely agree with the policy because of the fact that they would be able to build more on valuable real estate and would be contributing to the overall health of the watershed. A cap would be put on lot coverage, and the plan would only be offered to landowners with larger holdings.

4.7 – Innovative BMPs for New or Retrofit Projects:

The field of Low Impact Development has gained wider acceptance and implementation in recent years due to expanded research. Many BMPs are outlined in the Maine DEP's "Stormwater Management for Maine", vol. 3. However, innovation on these ideas is encouraged. WBRC has listed ideas for new LID BMPs, with ideas gathered both from past experiences and BMP manuals from states with similar climates as Maine.

- ☐ Stone-check/underdrained roadside swale soil filter
  This BMP combines a vegetated swale with check dams and an underdrained soil filter. Soil filters must typically be built in a relatively flat area to enable proper ponding and infiltration. In areas with steep slopes, a soil filter may not be able to be built with the proper slope; low check dams may be implemented within a swale to create smaller 18" deep ponding areas, to assist in retaining runoff until it can infiltrate the underdrained filter media. See figure 4.1 below.

  FIGURE 4.1 – STONE-CHECK UNDERDRAINED SWALE



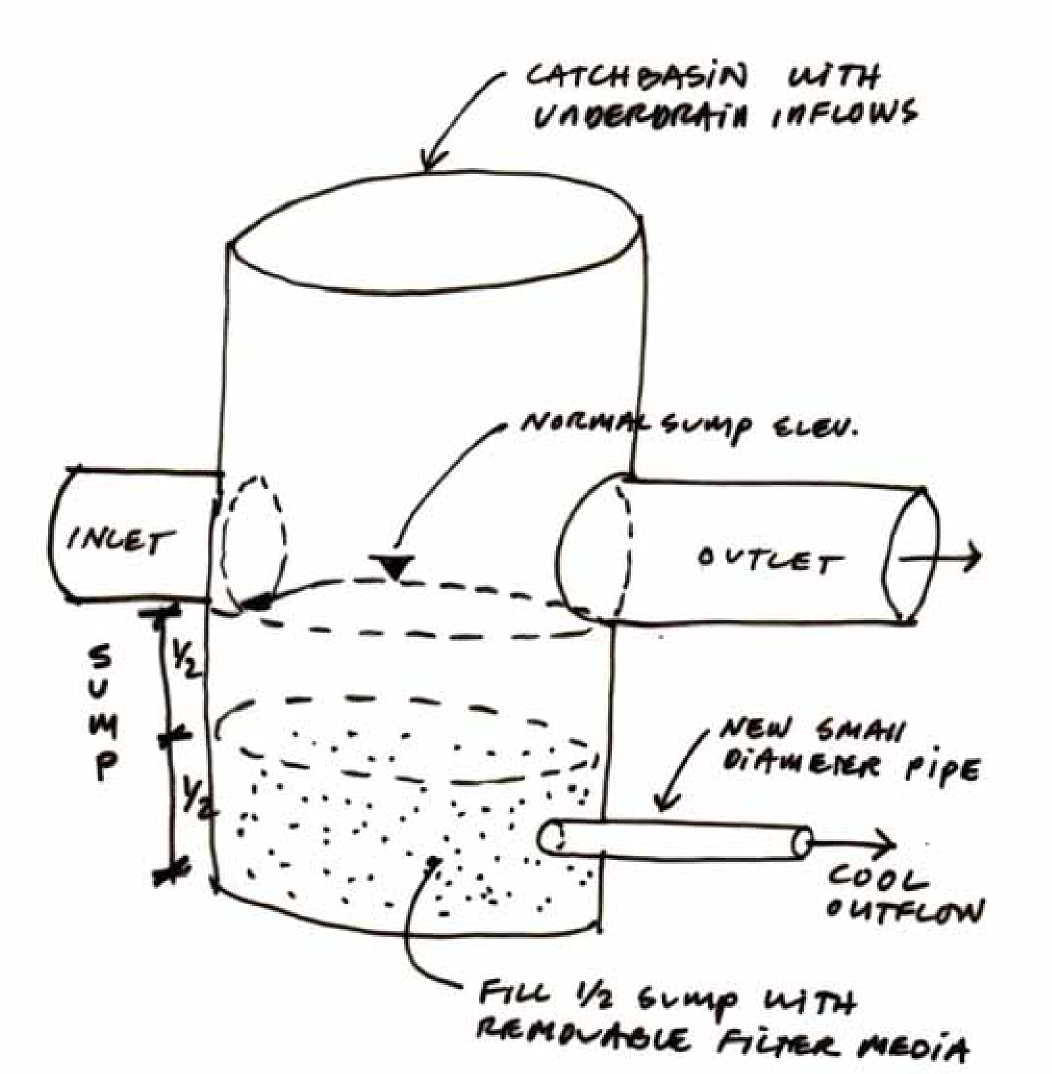
- ☐ Underdrained parking lot bioretention swale with overflow catch basin
  Bioretention swales are often used to treat highly polluted runoff with minimal area. However, storage is minimal. For larger storms, flooding of surrounding paved areas could be an issue. A catch basin placed above the infiltration surface

of the swale at a height of 18” (depending upon design considerations) would allow depths of water over that limit to drain harmlessly into an exit pathway, thereby eliminating flooding of the filter and reducing the strain on the entire system.

- Type ‘C’ underdrain in parking lot for simulating base flow
  In Maine, groundwater is a consideration when building new development. Underdrain pipes placed strategically throughout a development would collect the cooler water and would convey it directly to the receiving water body; this would replace some of the lost groundwater base flow and improve the thermal conditions of the stream during low flow conditions. The peak flows would not be an issue, as the groundwater flow would not increase as rapidly as surface runoff after a substantial storm.

- Stone-filtered catch basin with underdrain outlet
  In existing developments where stormwater systems were built to past recommendations, many systems convey underdrain flows directly into a retention/detention pond. This can heat up the water unnecessarily. A rip-rap basket placed near the end of a storm system pond inlet pipe would collect any discharge during dry weather and convey it with a narrow pipe directly into the stream. Larger flows would not be able to pass through the narrow pipe and would continue into the pond as usual. The stone would act as a filter to prevent debris and larger soil particles from plugging the small-diameter pipe.

FIGURE 4.2 – STONE-FILTERED CATCH BASIN WITH UNDERDRAIN OUTLET



- ☐ Wet retention basins obtain best performance

  It has been the experience of WBRC that wet retention basins outperform all other types of BMPs in most past design projects. It is recommended that instead of attempting to phase out such BMPs, effort be made to expand their use and improve upon design where performance does not achieve the desired success rate.

- ☐ 100' of 4"-6" buried underdrain pipe serves to cool runoff

  Many engineering firms in the state of Maine have been designing LID systems for several projects. The challenge of thermal reduction has been approached in many ways. It was found that a narrow pipe of 4"-6" in diameter would sufficiently cool runoff if the pipe were buried underground for a length of at least 100'. This would then discharge directly to the stream.

- ☐ Retrofit dry pond with permeable weirs

  Permeable weirs are an innovation that is widely used in northern states such as Wisconsin and Minnesota. A retrofit option, permeable weirs are used to enable detention BMPs retain water for treatment. The design consists of a slotted weir designed in such a way as to retain smaller storms. As the amount of runoff increases, more and more runoff passes through the slots in the weir. Very large flows would simply overtop the weir and pass directly into the receiving water body.

<u>FIGURE 4.3 – DRY POND RETROFIT WITH PERMEABLE WEIRS</u>

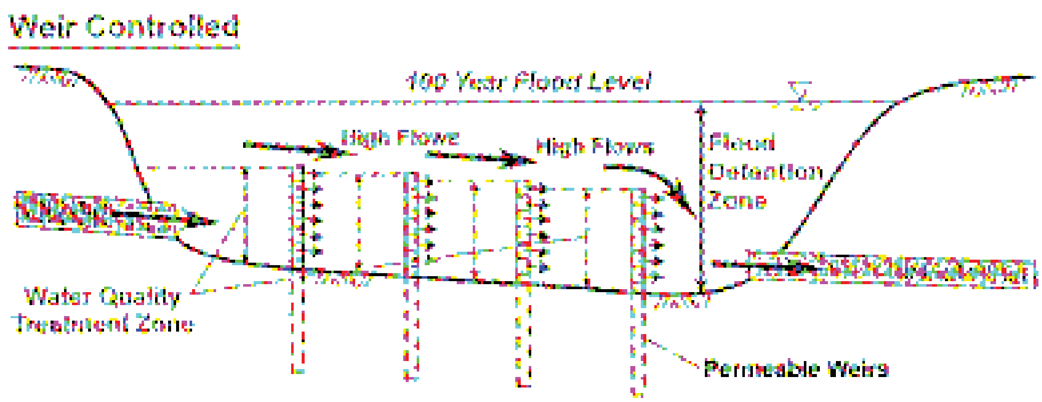


Figure 3: Dry Pond with Permeable Weir Control
Source: Klein, 1997

See also Appendix C for additional BMP designs from the Maine DEP's Stormwater Management for Maine, vol. III.

TABLE 4.0 - BMP RETROFIT MATRIX

● = applicable
○ = applicable with careful design
□ = existing

		Desc	BMP #					BFCU	Evergreen Woods	Quirk	Small section of Hogan Road	Quirk	Quirk	Small section of Hogan Road	Freeway	Bangor Ford	Bangor Dodge	Gas station	EMCC & Darling's Honda	United Technology Center	Freeway	Freeway	Wendy's and stream banks
		WBRC WS #		10	11	100	110	200	300	310	311	320	321	322	400	410	411	412	500	520	600	800	1000
		AREA (ACRES)		38.2	8.4	49.9	15.1	10.2	11.9	9.6	0.5	3.8	0.9	1.0	8.7	6.5	1.7	5.5	123.1	28.5	5.8	6.5	6.1
	HSG	A																					
		B				●																	
		C		●	●		●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●
		D																					
BMPs		Detention Basin	3-1, 3-2	●		●	●	●	●	□		□							●□	●			
		Wet Pond	4-1, 4-2	●		●	●	●	●										●□	●			
	Buffer	Veg. Buffer w/ Level Spreader	5-2								●	●	●	●			●						
		Downhill Side of Road	5-3																				
		Ditch Turn-Out	5-4								●	●	●	●			●						
		Residential	5-1	●		●																	
	Infiltration	Drywell	6-1																				
		Trench	6-2, 6-3																				
		Basin	6-4			●																	
	Filters	Veg. Soil Filter	7-1, 7-2, 7-5		●					●					●	●		●			●	●	●
		Bioret. Cell	7-3, 7-4								●	●	●	●			●						
	Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Flow Splitter	8-2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Level Spreader	8-3					□			●	●	●	●			●						
	Separator BMPs	WQ Inlet	9-1								●	●	●	●			●						
		Oil/Grit, Oil/Water Sep.	9-2								●	●	●	●			●						
		Proprietary Systems									●	●	●	●			●						
		LID	10-1, 10-2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	BMP Land Required	Small Area			●					●	●	●	●	●	●	●	●	●			●	●	●
		Large Area		●		●	●	●	●	□	●	□	●	●			●		●	●			
	Applicability	Peak Control		●	○	●	●	●	●	□	○	□	○	○	○	○	○	○	□	●	○	○	○
		WQ Control		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	□	●	●	●	●
		Pretreatment		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Conveyance		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Distribution		●	●	●	●	□	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

		Desc	BMP #	Freeway	Hampton Inn/99	Toys R Us	Lamey Wellehan etc.	East side Hogan Rd	Kmart etc	Maine Square Mall etc.	Stream banks	Arby's	Best Buy	Kmart etc	Retail	Retail	Tributary banks	Retail	Inn and gas station	Target	VCOM	Ridgewood	Upper watershed
		WBRC WS #		1010	1030	1040	1090	1091	1092	1093	1200	1210	1220	1230	1240	1270	1280	1290	1291	1292	1293	1294	1296
		AREA (ACRES)		10.2	5.2	10.1	2.6	9.9	12.2	7.1	5.2	1.3	4.6	2.9	2.2	1.6	4.5	1.4	3.7	9.7	2.2	11.8	81.6
	HSG	A																					
		B						●													●		
		C		●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●		●	●
		D																					
BMPs		Detention Basin	3-1, 3-2	●	□	●□		□	●											□		●□	●
		Wet Pond	4-1, 4-2	●		●			●													●	●
	Buffer	Veg. Buffer w/ Level Spreader	5-2				●					●	●	●	●	●	●	●	●		●		
		Downhill Side of Road	5-3									●	●	●	●	●	●	●	●				
		Ditch Turn-Out	5-4				●					●	●	●	●	●	●	●	●				
		Residential	5-1																				
	Infiltration	Drywell	6-1																		●		
		Trench	6-2, 6-3					●													●		
		Basin	6-4					●															
	Filters	Veg. Soil Filter	7-1, 7-2, 7-5		●			●		●	●									●			
		Bioret. Cell	7-3, 7-4				●					●	●	●	●	●	●	●	●		●		
	Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Flow Splitter	8-2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Level Spreader	8-3				●					●	●	●	●	●	●	●	●	□	●		
	Separator BMPs	WQ Inlet	9-1				●					●	●	●	●	●	●	●	●		●		
		Oil/Grit, Oil/Water Sep.	9-2				●					●	●	●	●	●	●	●	●		●		
		Proprietary Systems					●					●	●	●	●	●	●	●	●	□	●		
		LID	10-1, 10-2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	BMP Land Required	Small Area			●		●			●	●	●	●	●	●	●	●	●	●	●	●		
		Large Area		●	□	□	●	●	●			●	●	●	●	●	●	●	●	□	●	●	●
	Applicability	Peak Control		●	□	□	○	□	●	○	○	○	○	○	○	○	○	○	○	□	□	□	●
		WQ Control		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Pretreatment		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	□	●	●	●
		Conveyance		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	□	●	●	●
		Distribution		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	□	●	●	●

TABLE 4.0 - BMP RETROFIT MATRIX

● = applicable
○ = applicable with careful design
□ = existing

	Desc		Dunkin Donuts	Retail	Roadway section	Sylvan Rd New	Crossroads south	Grassy area	Crossroads north	Inn	Retail	Parking lots	Substation		Rangely Hall and part of Sylvan Rc
	WBRC WS #	BMP #	1297	1298	1299	1300	1410	1410B	1412	1413	1420	1500	1700	1710	1711
	AREA (ACRES)		1.3	1.0	0.4	1.5	3.4	5.0	4.4	5.3	3.9	4.7	0.9	6.7	11.1
HSG	A														
	B								●						
	C		●	●	●		●	●		●	●	●	●	●	●
	D					●									
BMPs	Detention Basin	3-1, 3-2					□		□		□				●
	Wet Pond	4-1, 4-2													●
Buffer	Veg. Buffer w/ Level Spreader	5-2	●	●	●	○	●		●		●	●	●		
	Downhill Side of Road	5-3				●						●	●		
	Ditch Turn-Out	5-4	●	●	●	○	●				●	●	●		
	Residential	5-1				○									
Infiltration	Drywell	6-1							●						
	Trench	6-2, 6-3							●						
	Basin	6-4													
Filters	Veg. Soil Filter	7-1, 7-2, 7-5						●		●				●	
	Bioret. Cell	7-3, 7-4	●	●	●	●	●		●		●	●	●		
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●	●	●	●	●	●
	Level Spreader	8-3	●	●	●	●	●		●		●	●	●		
Separator BMPs	WQ Inlet	9-1	●	●	●	●	●		●		●	●	●		
	Oil/Grit, Oil/Water Sep.	9-2	●	●	●	●	●		●		●	●	●		
	Proprietary Systems		●	●	●	●	●		●		●	●	●		
	LID	10-1, 10-2	●	●	●	●	●	●	●	●	●	●	●	●	●
BMP Land Required	Small Area		●	●	●	●	●	●		●	●	●	●	●	
	Large Area		●	●	●	●	□		●		□	●	●		●
Applicability	Peak Control		○	○	○	○	□	○	□	○	□	○	○	○	●
	WQ Control		●	●	●	●	●	●	●	●	●	●	●	●	●
	Pretreatment		●	●	●	●	●	●	●	●	●	●	●	●	●
	Conveyance		●	●	●	●	●	●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	●	●	●	●	●	●	●	●	●

	Desc		O. Sylvania					Freeway	Cinema	Oriental Jade	Lawn area	Freeway	Bangor Mall	Goodwill store
	WBRC WS #	BMP #	1712	1900	2100	2300	2500	2510	2511	2512	2513	2514	2550	2700
	AREA (ACRES)		12.0	0.5	5.0	3.8	3.4	25.2	9.2	6.7	7.4	3.2	74.3	4.1
HSG	A													
	B													
	C		●	●	●	●	●	●	●	●	●	●	●	●
	D													
BMPs	Detention Basin	3-1, 3-2	●					●	□				●□	
	Wet Pond	4-1, 4-2	●					●					●□	
Buffer	Veg. Buffer w/ Level Spreader	5-2		●	●	●	●					●		●
	Downhill Side of Road	5-3		●	●	●						●		●
	Ditch Turn-Out	5-4		●	●	●	●					●		●
	Residential	5-1												
Infiltration	Drywell	6-1											□	
	Trench	6-2, 6-3												
	Basin	6-4												
Filters	Veg. Soil Filter	7-1, 7-2, 7-5							●	●	●			
	Bioret. Cell	7-3, 7-4		●	●	●	●					●		●
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●	●	●	●	●
	Level Spreader	8-3		●	●	●	●					●		●
Separator BMPs	WQ Inlet	9-1		●	●	●	●					●		●
	Oil/Grit, Oil/Water Sep.	9-2		●	●	●	●					●		●
	Proprietary Systems			●	●	●	●					●	□	●
	LID	10-1, 10-2	●	●	●	●	●	●	●	●	●	●	●	●
BMP Land Required	Small Area			●	●	●	●		●	●	●	●		●
	Large Area		●	●	●	●	●	●	□			●	●	●
Applicability	Peak Control		●	○	○	○	○	●	□	○	○	○	□	○
	WQ Control		●	●	●	●	●	●	●	●	●	●	□	●
	Pretreatment		●	●	●	●	●	●	●	●	●	●	□	●
	Conveyance		●	●	●	●	●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	●	●	●	●	●	●	●	●

	Desc		Small section of Stillwater Ave	Happy China	Sportshoe center	Lawn area	Mall lawn	Penn Plaza	Penn Plaza east	JoAnn & golf store	Widewaters	The Avenue	Section of Stillwater Ave	Talbot's	Carpet One	Building
	WBRC WS #	BMP #	2710	2720	2730	2740	2750	2900	2910	2920	3110	3120	3130	3140	3150	3160
	AREA (ACRES)		0.3	1.7	1.1	1.6	5.9	8.0	3.5	4.5	43.4	5.6	0.2	1.2	2.6	3.6
HSG	A															
	B															
	C		●	●	●	●	●	●	●	●	●		●	●		●
	D														●	
BMPs	Detention Basin	3-1, 3-2									●□	□				
	Wet Pond	4-1, 4-2									●					
Buffer	Veg. Buffer w/ Level Spreader	5-2	●	●	●	●			●	●				●	○	●
	Downhill Side of Road	5-3				●			●	●						
	Ditch Turn-Out	5-4	●			●			●	●				●	○	●
	Residential	5-1														
Infiltration	Drywell	6-1														
	Trench	6-2, 6-3														
	Basin	6-4														
Filters	Veg. Soil Filter	7-1, 7-2, 7-5					●	●				●				
	Bioret. Cell	7-3, 7-4	●	●	●	●			●	●	□		●	●	●	●
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Level Spreader	8-3	●	●	●	●			●	●			●	●	●	●
Separator BMPs	WQ Inlet	9-1	●	●	●	●			●	●			●	●	●	●
	Oil/Grit, Oil/Water Sep.	9-2	●	●	●	●			●	●			●	●	●	●
	Proprietary Systems		●	●	●	●			●	●		□	●	●	●	●
	LID	10-1, 10-2	●	●	●	●	●	●	●	●	●	●	●	●	●	●
BMP Land Required	Small Area		●	●	●	●	●	●	●	●		●	●	●	●	●
	Large Area		●	●	●	●			●	●	●	□	●	●	●	●
Applicability	Peak Control		○	○	○	○	○	○	○	○	□	□	○	○	○	○
	WQ Control		●	●	●	●	●	●	●	●	□	□	●	●	●	●
	Pretreatment		●	●	●	●	●	●	●	●	●	□	●	●	●	●
	Conveyance		●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	●	●	●	●	●	●	●	●	●	●

5.0 – Resources:

5.1 Contour information was obtained from city digital mapping data, record drawings provided by watershed stakeholders, and the Maine Office of GIS. Contours are at 10-foot intervals except where supplemented with archive data.

5.2 Information about the Hydrocad program's hydrology methods and practices was obtained from the program's Help files, and from the company web site, available at <http://www.hydrocad.net/>.

5.3 Information about existing projects such as Bangor Mall and EMCC was obtained from existing SLODA documents.

5.4 Water quality information was obtained from EPA-NE Maine water quality standards 1998 303(d) list, available at <http://www.epa.gov/water/states/me.html>.

5.5 The Minnesota Urban Small Sites BMP Manual, published in July 2001, was used extensively for BMP innovation ideas. As the climate of Minnesota is similar to that of Maine, this manual is highly recommended for its usefulness in designing and improving effective BMPs. The manual is available free of charge in PDF format at <http://www.metrocouncil.org/environment/Watershed/BMP/manual.htm>.

5.6 Information about current zoning standards was taken from the Laws and Ordinances of the City of Bangor, Chapter 165 Land Development.

6.0 – References:

6.1 "Caribou Bog Wetland Complex", Maine Natural Areas Program, Augusta, Maine, (2002).

6.2 Endreny, Theodore, "Fluvial Geomorphology", College of Environmental Science and Forestry, State University of New York, <http://www.fgmorph.com/>.

6.3 "Flood Insurance Study, City of Bangor, Maine", Federal Emergency Management Agency, Washington, D.C., (March 2004).

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6.5 Murphy, John L., et al, "Insystem Storage Capacity Enhances Sewer System Operation", Office of Infrastructure and Development Support, City of Bangor, Maine, (June 2003).

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6.8 Parish, John, "Penjajawoc Stream Fluvial Geomorphological Study", Parish Geomorphic, Georgetown, Ontario, (March 2003).

6.9 -----------, "Penjajawoc Stream Analysis and Interpretation", Parish Geomorphic, Georgetown, Ontario, (June 2006).

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6.11 "Part 630 Hydrology", National Engineering Handbook, Natural Resources Conservation Service, United States Department of Agriculture, Washington, D.C., (November 1998).

6.12 "Penjajawoc Stream Storm Water Management Model", ENSR Corporation, Westford, Massachusetts, (March 2006).

6.13 "Rainfall Frequency Atlas for the Northeast, TP-40", Soil Conservation Service, United States Department of Agriculture, Amherst, Massachusetts, (September 1990).

6.14 Schueler, Thomas R. and Heather K. Holland, "The Importance of Imperviousness", *The Practice of Watershed Protection,* Center for Watershed Protection, Ellicott City, Maryland, (2000).

6.15 "Soil Survey, Penobscot County Maine", Soil Conservation Service and University of Maine Agricultural Experiment Station, United States Department of Agriculture, (1963).

6.16 "Stormwater Management for Maine", Maine Department of Environmental Protection, Augusta, Maine, (January 2006), vols. I, III.

6.17 "Urban Hydrology for Small Watersheds, TR-55", Soil Conservation Service, United States Department of Agriculture, Washington, D.C., (1986).

6.18 "Water Resources of Maine", United States Geological Survey, United States Department of the Interior, <http://me.water.usgs.gov/>, (July 2006).

Appendix A –
Supplemental Items, Maps & Appendices

Figure A-1 Site Location Map
Figure A-2 Stream Reach Identification
FIRM Maps (3)
Table A-1 Referenced Record Documents
Figure A-3 Subwatershed Identification
Figure A-4 Proposed BMP Retrofit Subareas
Figure A-5 On-Site Soil Types
USDA Soil Survey Maps (4)
HY101-108 Subwatershed Grid Maps

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Appendix A – Supplemental Items and Appendices:

a. Figure A-1 Site Location Map:

USGS map depicting overall watershed and location, watershed boundary, stream names, locations of existing or prior beaver activity, and existing BMPs.

b. Figure A-2 Stream Reach Identification:

Map depicting site topography and stream stationing.

c. FIRM Maps:

Three (3) 11x17 color "FIRMETTE" maps; obtained from FEMA's Flood Insurance Study (FIS) program web site: <http://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1>

d. Table A-1 Referenced Record Document List:

A list of all referenced record documents is included. Listed are scanned PDF documents obtained from Bangor City Hall, as well as documents from WBRC archives.

e. Figure A-3 Subwatershed Identification:

Map detailing outlined subcatchment areas and numerical classification.

f. Figure A-4 Proposed BMP Retrofit Subareas:

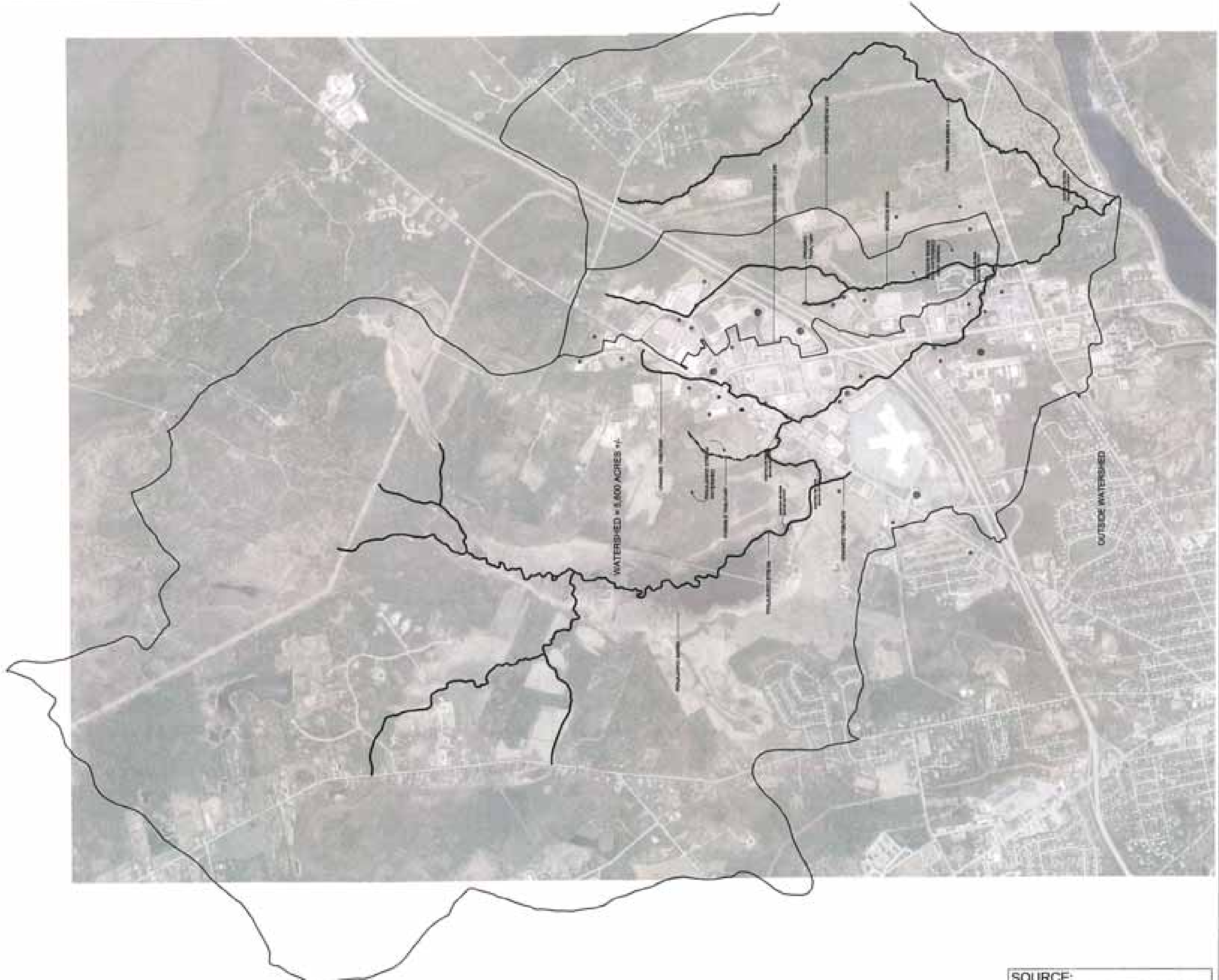
Map of locations of proposed BMP retrofit improvement subareas.

g. Figure A-5 Soils:

Map depicting soil types in the study area. See also four (4) USDA soil survey maps circa 1963, Penobscot County, # 222, 230, 231, & 239.

h. HY101-108 Subwatershed Grid Maps:

Eight (8) detailed grid maps depicting subcatchment areas including Tc paths, reach paths (Tt), and pond locations.



SOURCE:
AERIAL PHOTO MEOGIS 2004.

STORM WATER BMP RETROFIT DESIGN PROJECT

SITE LOCATION MAP
FIG. A-1

LOCATION MAP:

3/14/07

WBRC PROJECT # 3182.00

GRAPHIC SCALE: 0 — 1000' — 2000' — 4000'

MAG. NORTH

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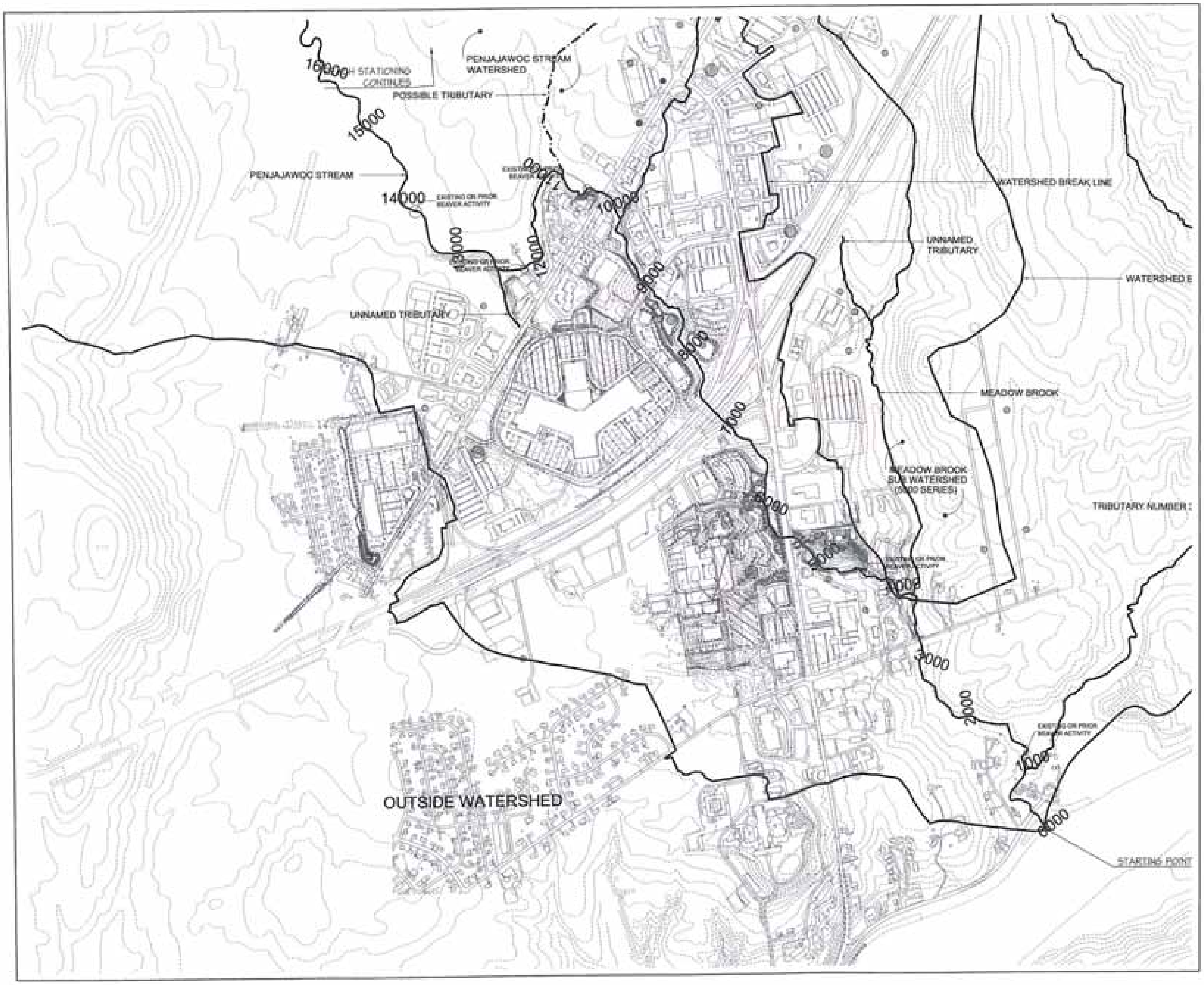


STORM WATER BMP RETROFIT DESIGN PROJECT

STREAM REACH IDENTIFICATION

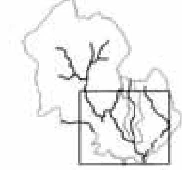
FIG. A-2

SOURCE:
USGS METADATA FROM MEOGIS.

LOCATION MAP:

3/14/07

INDEX 1"=2000'



WBRC PROJECT # 3182.00

GRAPHIC SCALE: 0 — 500' — 1000' — 2000'

MAG. NORTH

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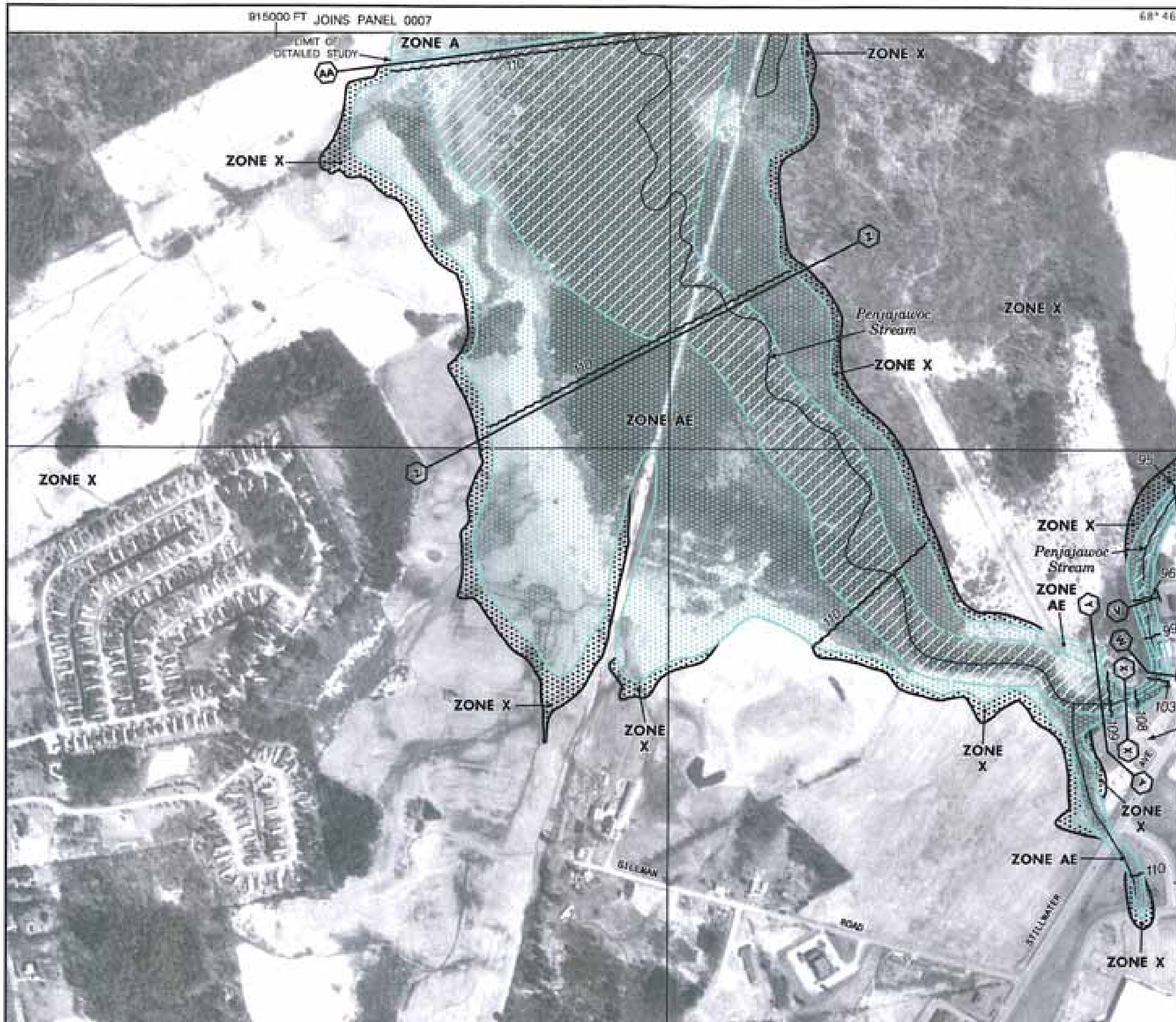
Bangor, Maine and Sarasota, Florida



...nal Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET

NFIP NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0012 C

FIRM
FLOOD INSURANCE RATE MAP

CITY OF
BANGOR,
MAINE
PENOBSCOT COUNTY

PANEL 12 OF 21

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BANGOR, CITY OF	230010	0012	C

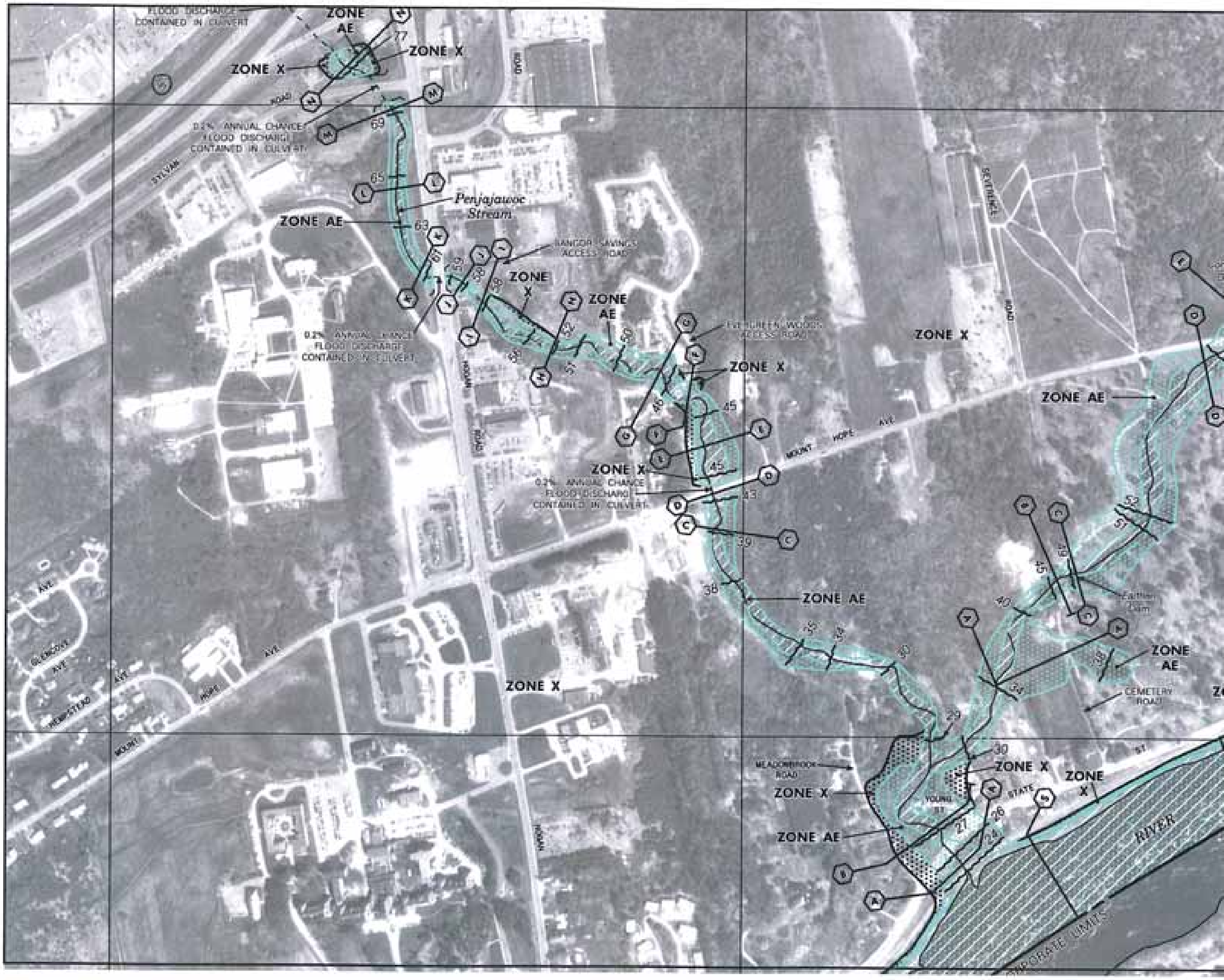
Notice to User: The Map Number shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

MAP NUMBER
23019C0012 C

MAP REVISED
MARCH 4, 2002

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov



...onal Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0013 C

FIRM
FLOOD INSURANCE RATE MAP

CITY OF
BANGOR,
MAINE
PENOBSCOT COUNTY

PANEL 13 OF 21

MAP NUMBER
2301020013 C

MAP REVISED
MARCH 4, 2002

Federal Emergency Management Agency

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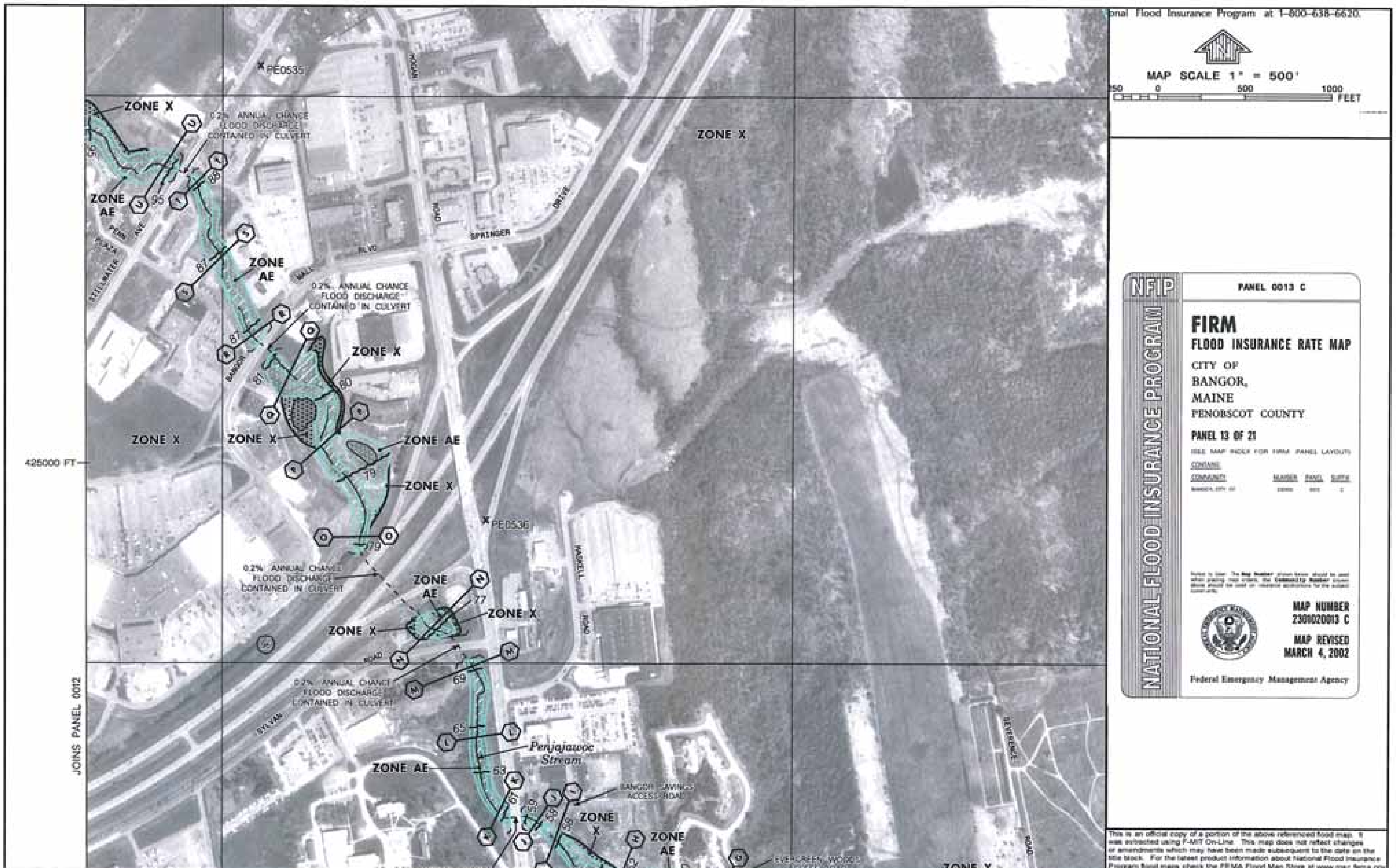

onal Flood Insurance Program at 1-800-638-6620.
MAP SCALE 1" = 500'
250 0 500 1000 FEET
NFIP
NATIONAL FLOOD INSURANCE PROGRAM
PANEL 0013 C
FIRM
FLOOD INSURANCE RATE MAP
CITY OF
BANGOR,
MAINE
PENOBSCOT COUNTY
PANEL 13 OF 21
MAP NUMBER
2301020013 C
MAP REVISED
MARCH 4, 2002
Federal Emergency Management Agency
ZONE X
ZONE AE
0.2% ANNUAL CHANCE FLOOD DISCHARGE CONTAINED IN CULVERT
PE0535
PE0536
HOGAN ROAD
SPRINGER DRIVE
BANGOR MALL BLVD
STILLWATER PLAZA
PENN AVE
HASKELL ROAD
SYLVAN ROAD
SEVERENCE ROAD
Penjajawoc Stream
BANGOR SAVINGS ACCESS ROAD
EVERGREEN WOODS ACCESS ROAD
425000 FT
JOINS PANEL 0012

TABLE A-1
REFERENCED RECORD DOCUMENTS
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072705 FEMA FLOOD INSURANCE MAPS_MAPINDEX.PDF
2553BFCU CS040.DWG
2747.90 bsb hogan road.dwg
2789_c_siteplans.dwg
318200 104__toys r us storm data.pdf
318200 105__smokey bones storm data.pdf
318200 109__applebee's short storm data.pdf
318200 109__applebee's storm data.pdf
318200 109__vansyckle hogan road storm data.pdf
318200 1201__arby's storm letter.pdf
318200 1208__asian palace storm data.pdf
318200 1210 CITGO CAR WASH.PDF
318200 1211 MCQUIKS OILUBE_C2.PDF
318200 1211 MCQUIKS OILUBE_C3.PDF
318200 1211__dunkin donuts storm data.pdf
318200 1211__target storm data.pdf
318200 1214__stillwater retail.pdf
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318200 29__stillwater realty storm data.pdf
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318200 5__varney new.pdf
318200 5__varney old.pdf
318200 5__world over imports stormdata.pdf
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318200_506_CITYHALL PLANS_HQ (BURLINGTON)_L3.PDF
318200_506_CITYHALL PLANS_HQ (BURLINGTON)_L4.PDF
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EMCC-Stormwater.pdf
mall storm data.pdf
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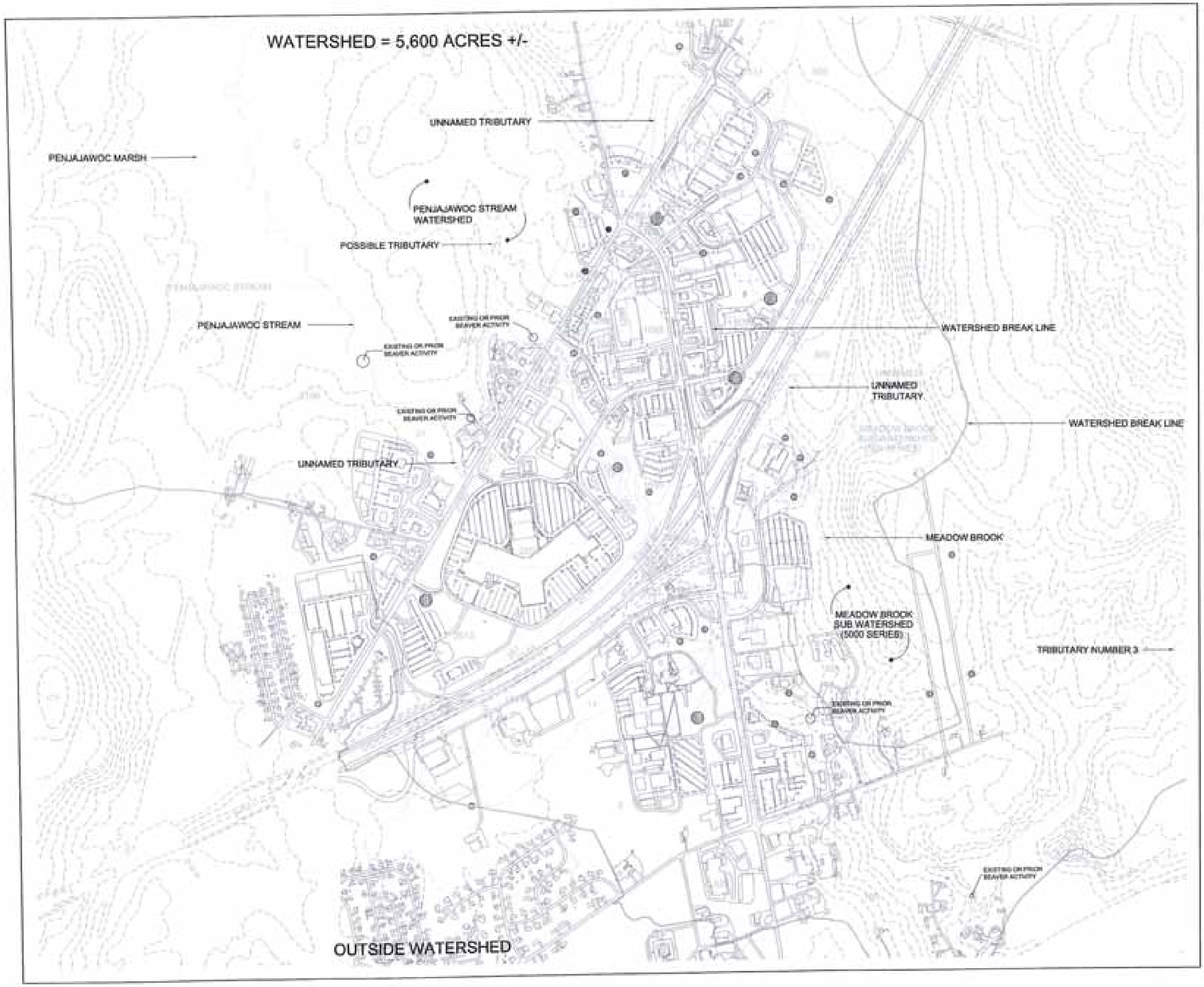


STORM WATER BMP RETROFIT DESIGN PROJECT

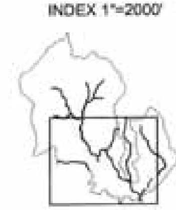
SUBWATERSHED IDENTIFICATION
FIG. A-3

SOURCE:
USGS METADATA FROM MEOGIS.

LOCATION MAP:

3/14/07

INDEX 1"=2000'



WBRC PROJECT # 3182.00

0 500' 1000' 2000'
GRAPHIC SCALE

N
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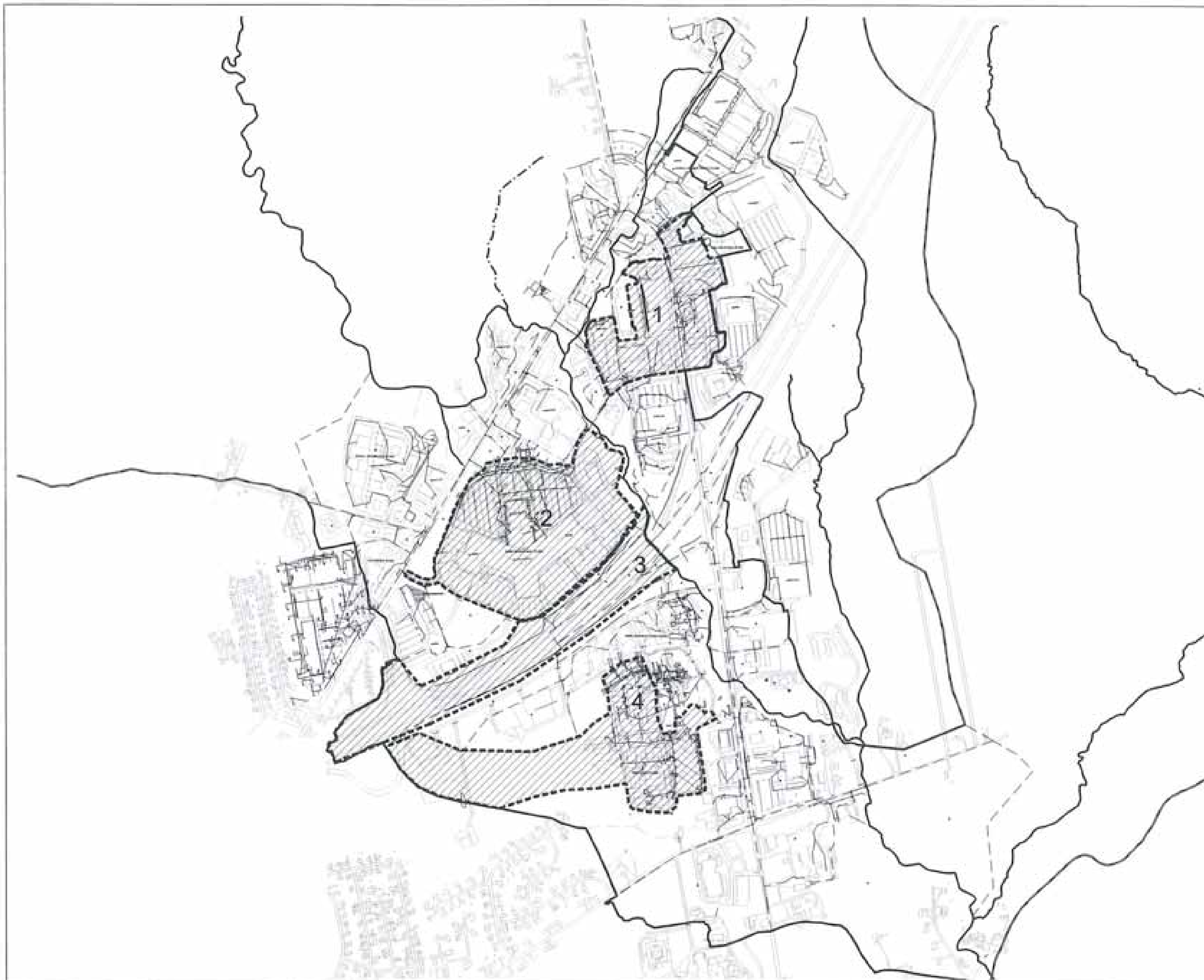


STORM WATER BMP RETROFIT DESIGN PROJECT

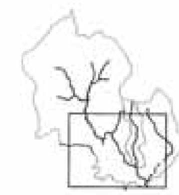
PROPOSED BMP RETROFIT SUBAREAS
FIG. A-4

NOTE: THIS PLAN REPRESENTS EXISTING OR PERMITTED PROJECTS AS OF 9/13/2006

LOCATION MAP:

3/14/07

INDEX 1"=2000'



WBRC PROJECT # 3182.00

0 500' 1000' 2000'
GRAPHIC SCALE

N
MAG. NORTH

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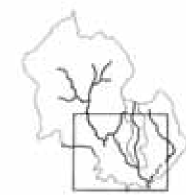
STORM WATER BMP RETROFIT DESIGN PROJECT

ON-SITE SOIL TYPE
FIG A-5

SOURCE:
USDA SOILS MAPS # 222, 230, 231, 239..

LOCATION MAP: 3/14/07



WBRC PROJECT # 3182.00

GRAPHIC SCALE: 0 500' 1000' 4000'

MAG. NORTH

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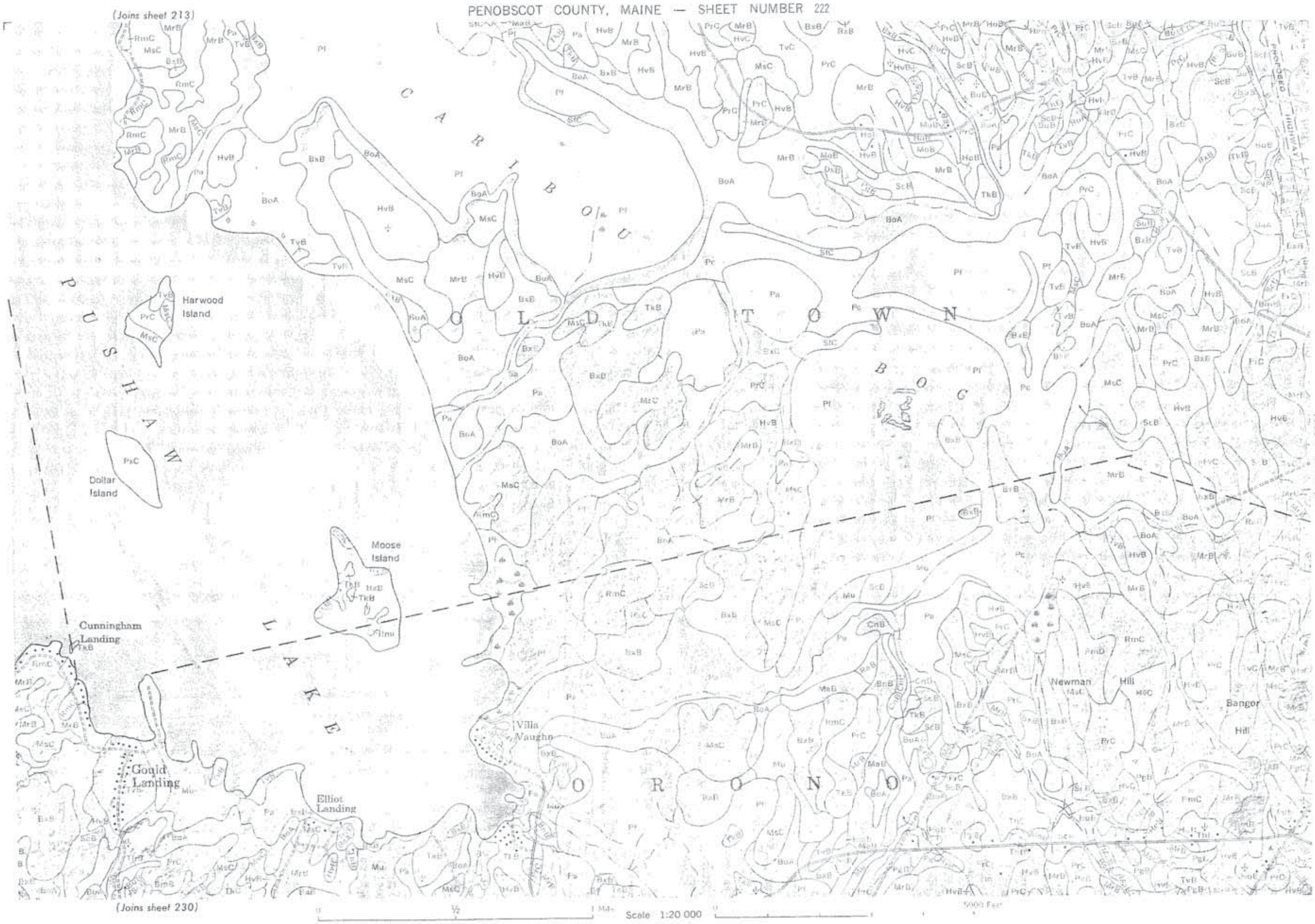
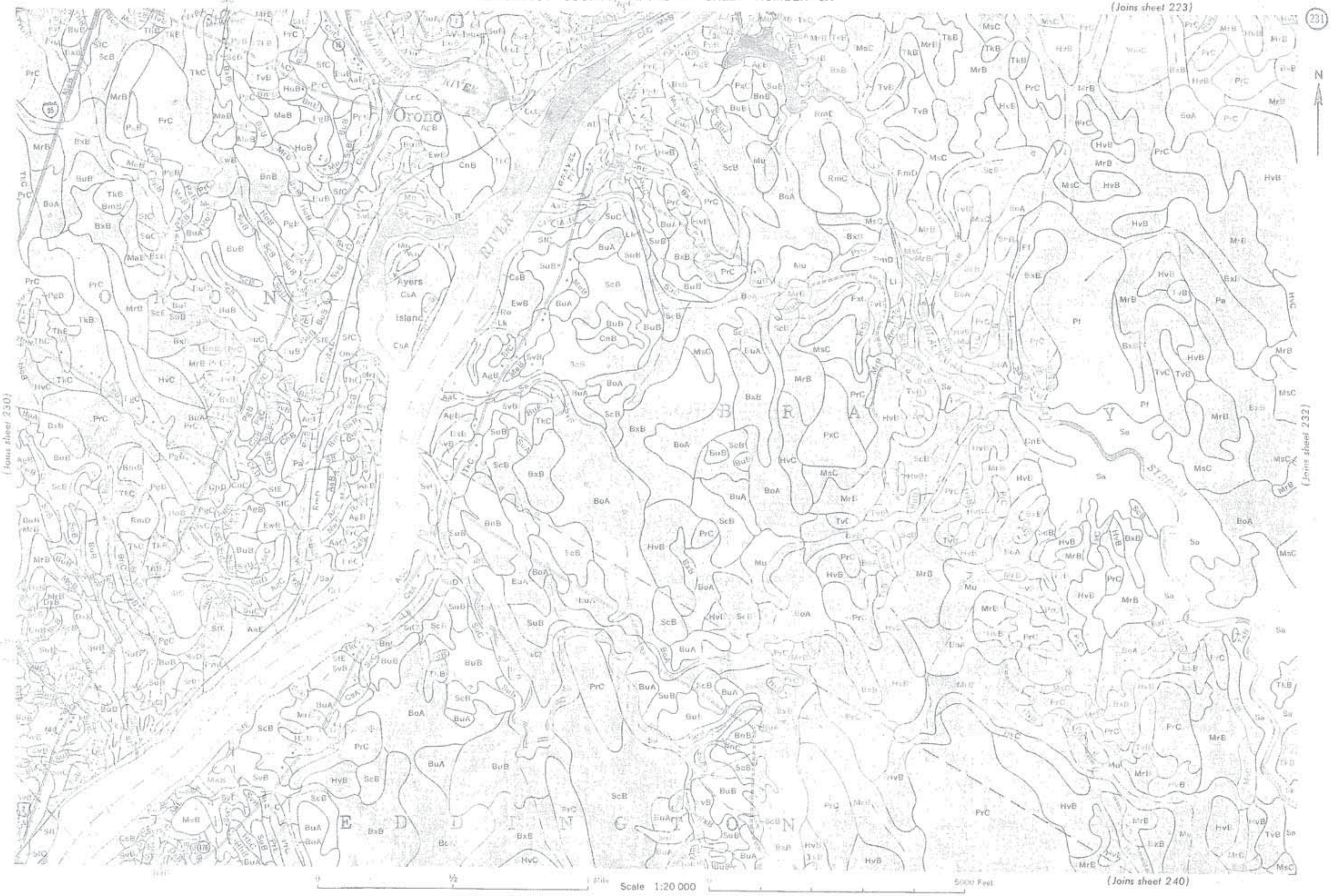
PENOBSCOT COUNTY, MAINE — SHEET NUMBER 222



PENOBSCOT COUNTY, MAINE — SHEET NUMBER 230

PENOBSCOT COUNTY, MAINE — SHEET NUMBER 231



(Joins sheet 230)

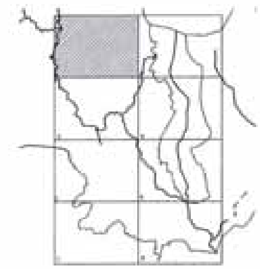
239

STORM WATER BMP RETROFIT DESIGN PROJECT

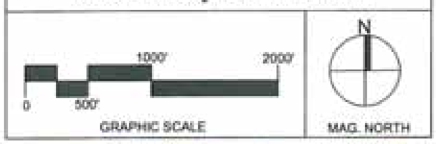
SUBWATERSHED GRID 1
HY101

SOURCE:
AERIAL PHOTO MEOGIS 2004.

LOCATION MAP: 3/14/07



WBRC PROJECT # 3182.00



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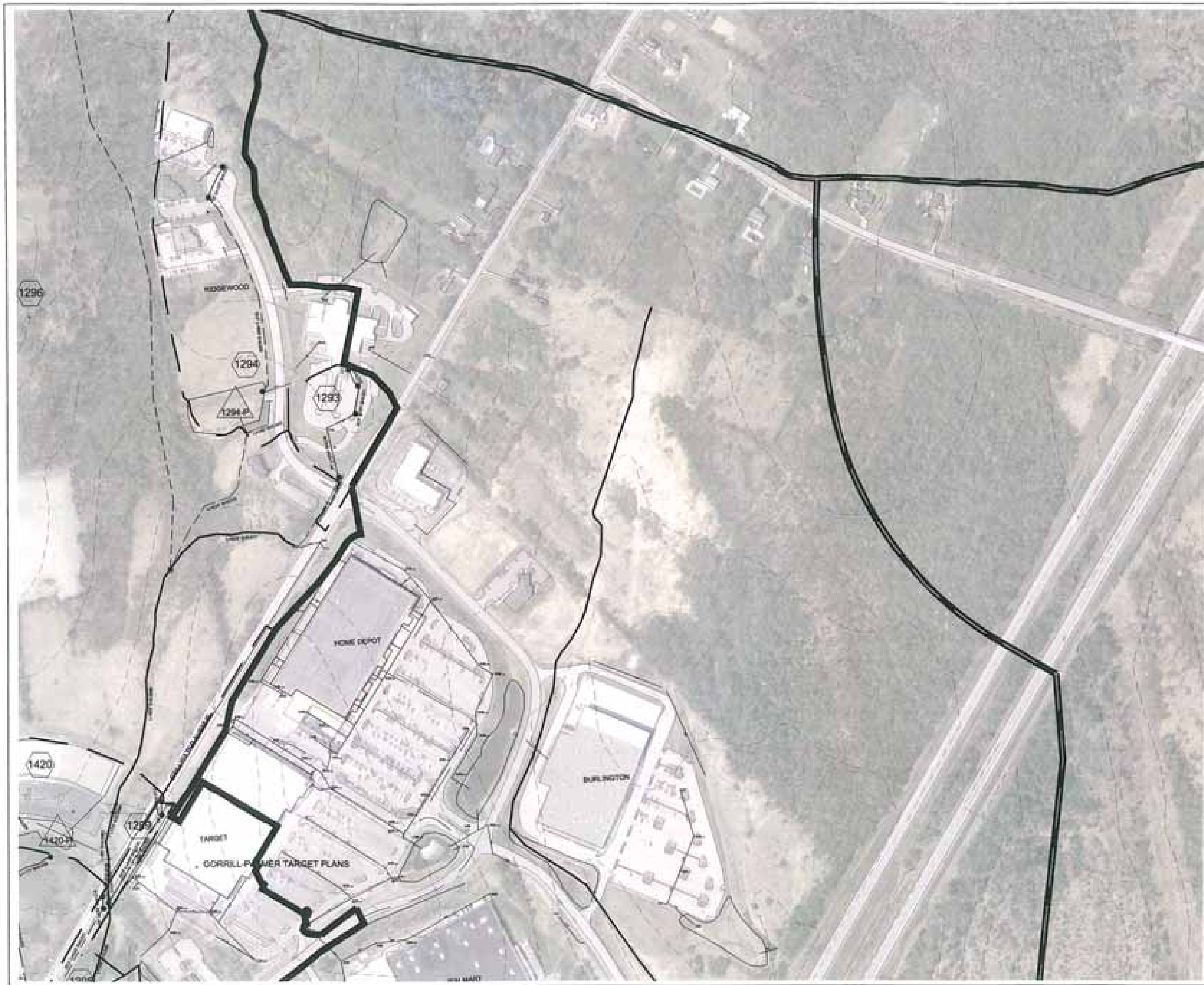
Bangor, Maine and Sarasota, Florida

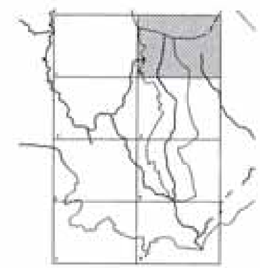


STORM WATER BMP RETROFIT DESIGN PROJECT

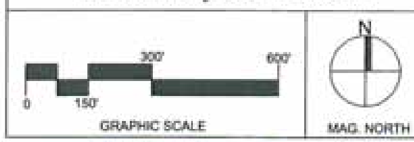
SUBWATERSHED GRID 2
HY102

SOURCE:
AERIAL PHOTO MEOGIS 2004.

LOCATION MAP: 3/14/07



WBRC PROJECT # 3182.00



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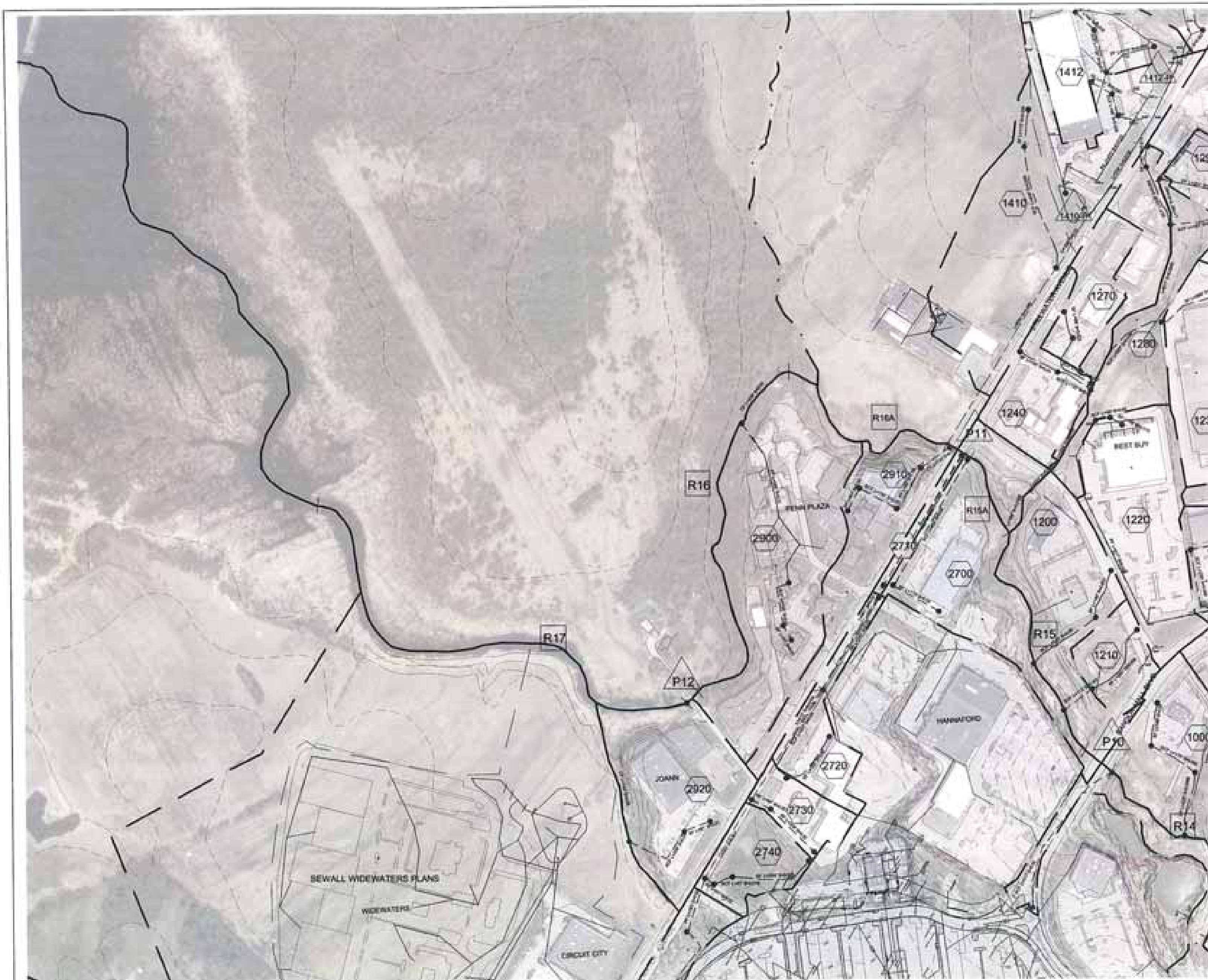
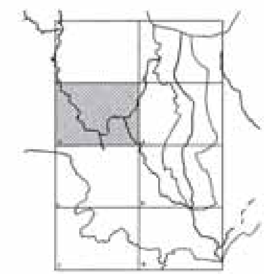


STORM WATER BMP RETROFIT DESIGN PROJECT

SUBWATERSHED GRID 3
HY103

SOURCE:
AERIAL PHOTO MEOGIS 2004.

LOCATION MAP: 3/14/07



WBRC PROJECT # 3182.00

0 150' 300' 600'
GRAPHIC SCALE

N
MAG. NORTH

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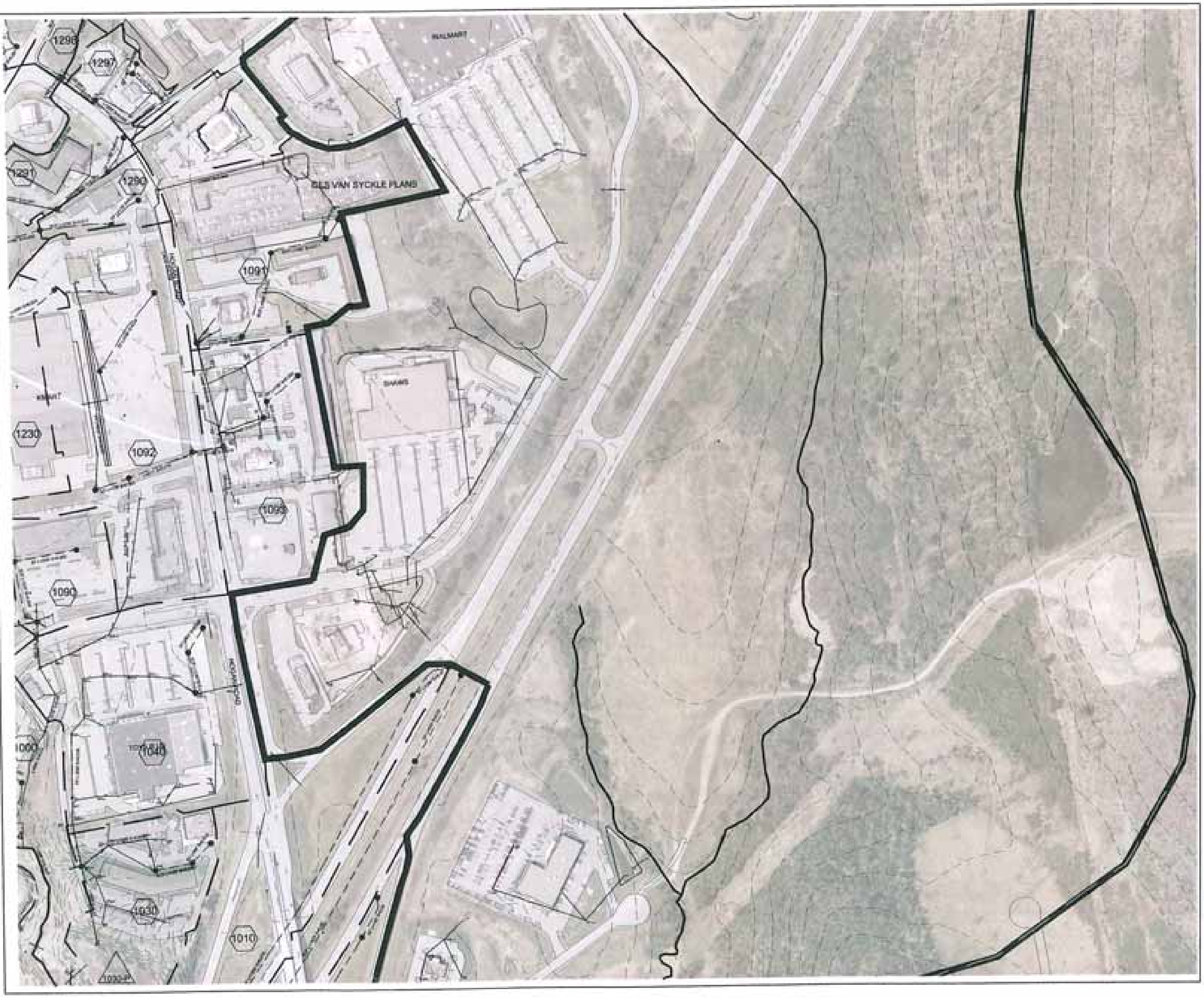
Bangor, Maine and Sarasota, Florida



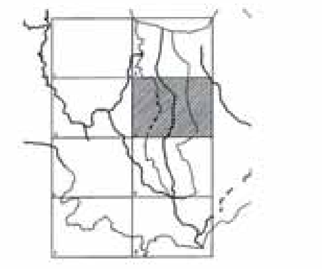
STORM WATER BMP RETROFIT DESIGN PROJECT

SUBWATERSHED GRID 4
HY104

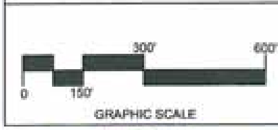
SOURCE:
AERIAL PHOTO MEOGIS 2004.

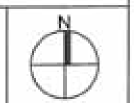
3/14/07

LOCATION MAP:



WBRC PROJECT # 3182.00





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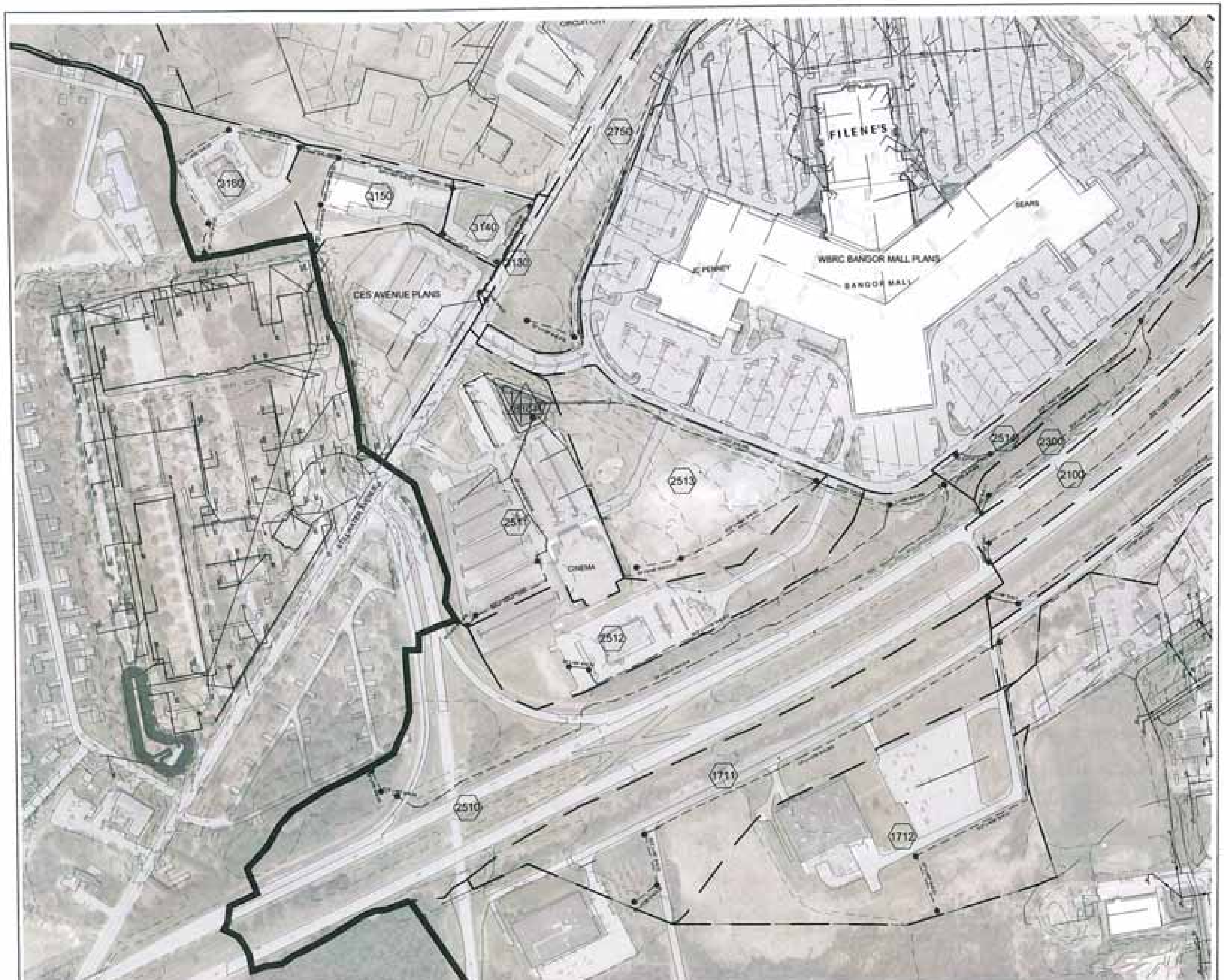
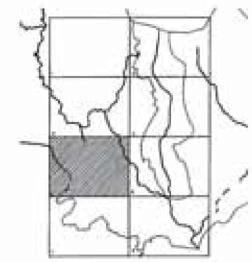


STORM WATER BMP RETROFIT DESIGN PROJECT

SUBWATERSHED GRID 5
HY105

SOURCE:
AERIAL PHOTO MEOGIS 2004.

LOCATION MAP: 3/14/07



WBRC PROJECT # 3182.00

0 150' 300' 600'
GRAPHIC SCALE

N
MAG. NORTH

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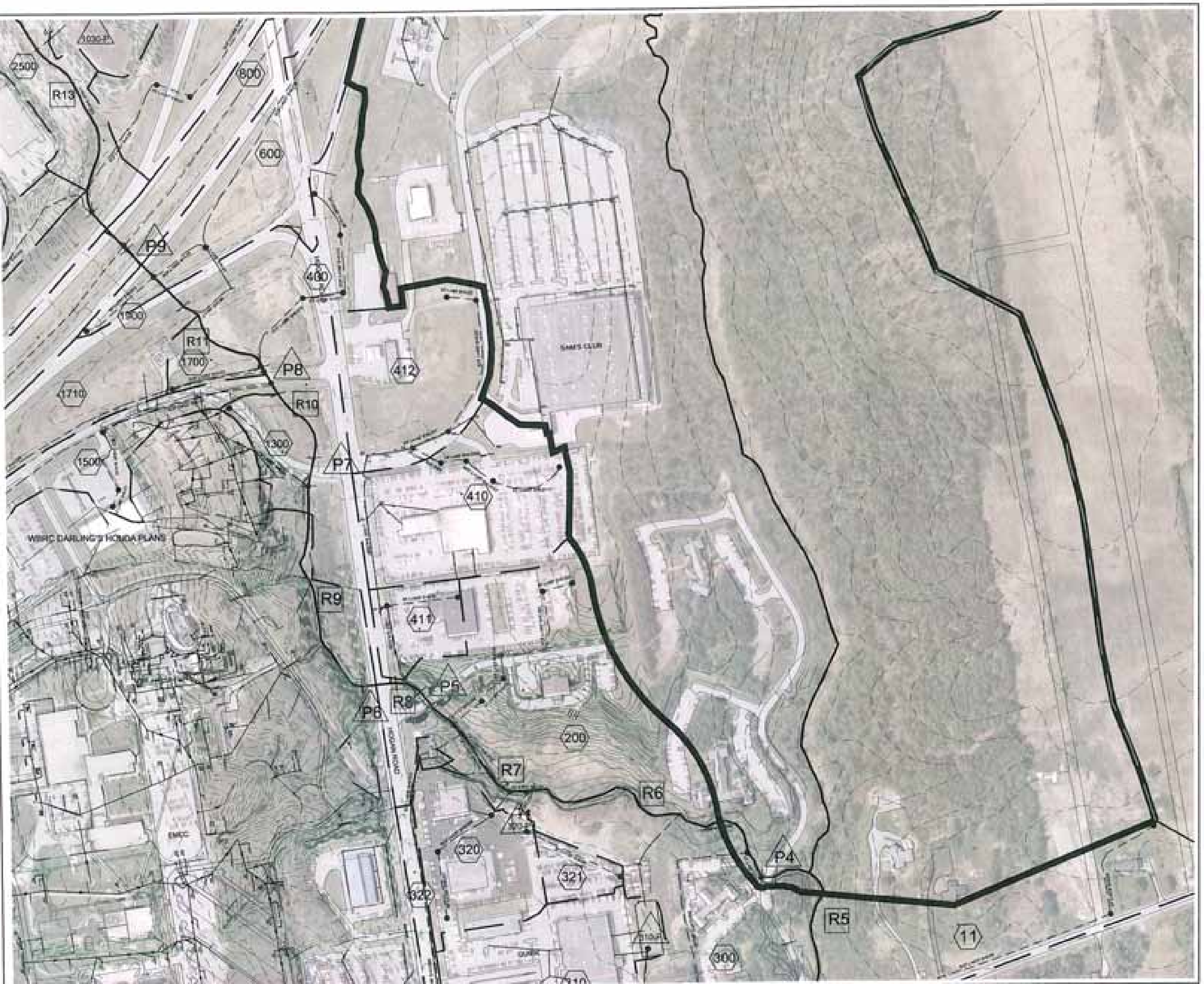
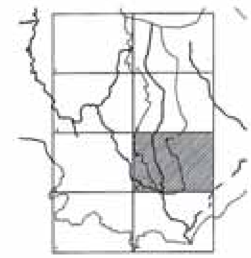


STORM WATER BMP RETROFIT DESIGN PROJECT

SUBWATERSHED GRID 6
HY106

SOURCE:
AERIAL PHOTO MEOGIS 2004.

LOCATION MAP: 3/14/07



WBRC PROJECT # 3182.00

0 150' 300' 600'
GRAPHIC SCALE

N
MAG. NORTH

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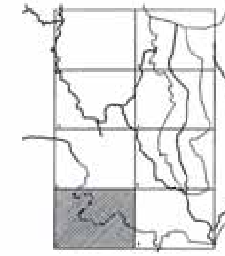
STORM WATER BMP RETROFIT DESIGN PROJECT

SUBWATERSHED GRID 7
HY107

SOURCE:
AERIAL PHOTO MEOGIS 2004.

LOCATION MAP:

3/14/07



WBRC PROJECT # 3182.00

N
MAG. NORTH

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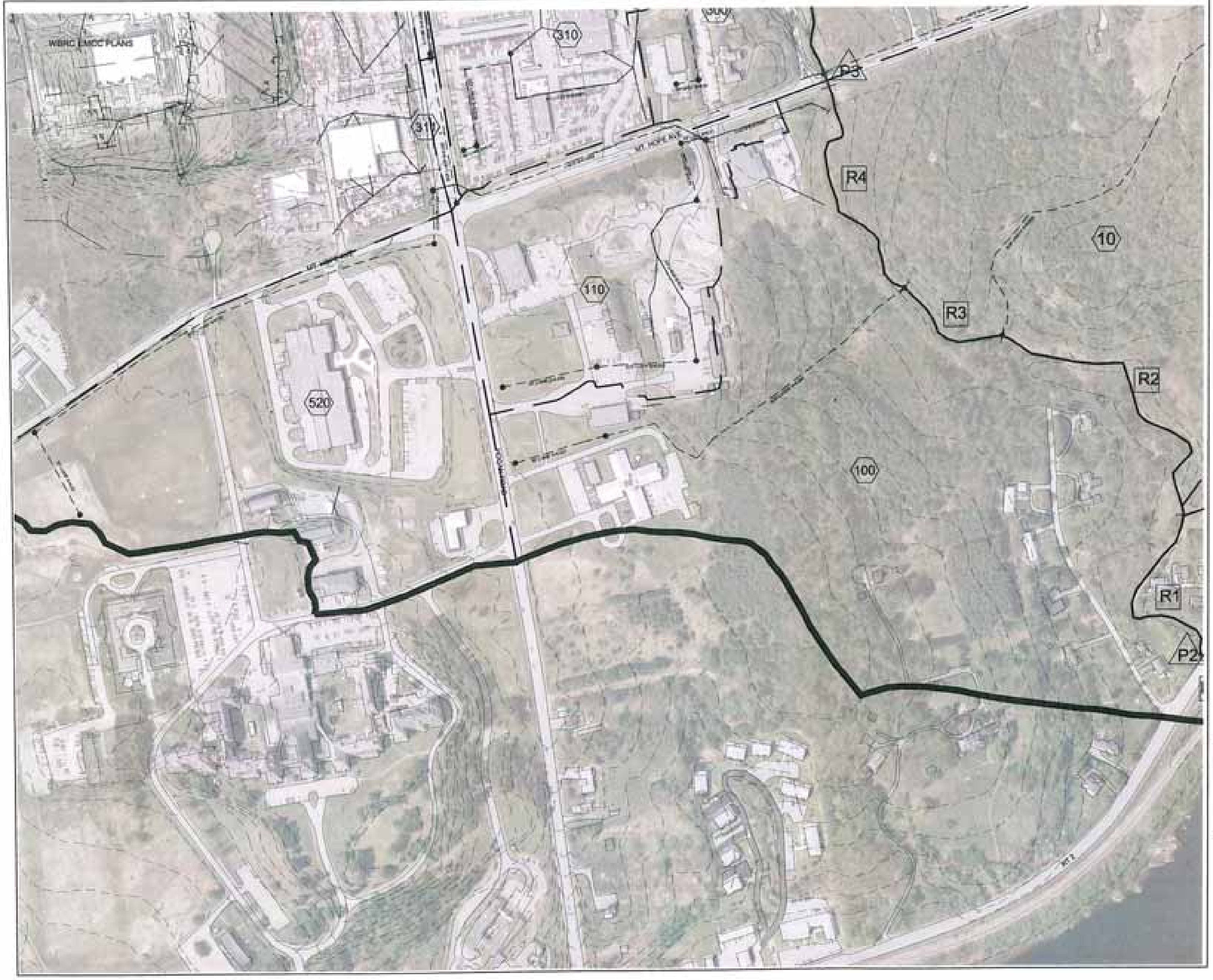


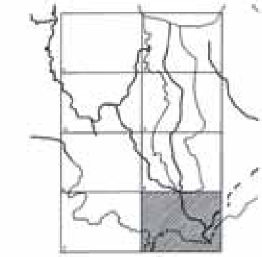
STORM WATER BMP RETROFIT DESIGN PROJECT

SUBWATERSHED GRID 8
HY108

SOURCE:
AERIAL PHOTO MEOGIS 2004.

LOCATION MAP:

3/14/07



WBRC PROJECT # 3182.00

0 150' 300' 600'
GRAPHIC SCALE

N
MAG. NORTH

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Appendix B –
Hydrologic Modeling Results

Table B8 Subwatershed Attributes
Hydrocad Routing Diagrams

Appendix B – Hydrologic Modeling Results:

This report is intended to accompany and clarify hydrologic calculations compiled by WBRC Architects / Engineers for the Penjajawoc study area. Included in the following section is a description of methods and assumptions used in compiling said model.

Modeling Assumptions:

The stormwater runoff evaluation was developed in accordance with the methodology outlined and implemented within the "HYDROCAD" stormwater modeling system. The "HYDROCAD" modeling system was developed using techniques from the SCS TR-20 and TR-55. The 1-year, 2-year, 10-year, 25-year, 100-year, and 500-year; 24-hour, Type III storm events were used to calculate the peak rates of runoff for the watershed.

TABLE B1 – RAINFALL AMOUNTS

EVENT	RAINFALL (INCHES)
1	2.4
2	2.7
10	4.1
25	4.7
100	5.9
500	6.9

Based on the above "Methodology", the following modeling assumptions were incorporated into the calculations:

- Per the Penobscot County Soil Survey of 1962, soils were classified according to Hydrologic Soil Group. Although the majority of soils were found to be Type C, all four types A, B, C, and D were present in the watershed. Distinction was made where possible; watersheds were not assumed to be all of one soil type as is commonly done in smaller projects. See Appendix A for figure A-5 for on-site soil types and USDA soil survey maps.

- The runoff curve numbers represented within the analysis identify the site characteristics for impervious areas, wooded areas, and grass cover. The following list represents the "Curve Numbers (CN)" used for this analysis:

TABLE B2 – CURVE NUMBERS

CURVE NUMBER	DESCRIPTION	SOIL GROUP
98	Paved parking lots, roofs, driveways, etc.	all
98	Paved; curbs and storm sewers	all
61	Good condition grass cover > 75%	B
74	Good condition grass cover > 75%	C
80	Good condition grass cover > 75%	D
69	Fair condition grass cover 50% to 75%	B
79	Fair condition grass cover 50% to 75%	C
84	Fair condition grass cover 50% to 75%	D
79	Poor condition grass cover < 50%	B
86	Poor condition grass cover < 50%	C
89	Poor condition grass cover < 50%	D
30	Woods, good	A
55	Woods, good	B
58	Woods/grass combination good	B
72	Woods/grass combination good	C
79	Woods/grass combination good	D
70	Brush, fair	C
77	Brush, fair	D

Weighted average Curve Numbers for individual watersheds ranged from 68 to 98.

- Typically, the time of concentration path within each watershed (subcatchment) was identified by sheet flow (300' maximum); shallow concentrated flow (paved, unpaved, grassed and wooded); pipes, and ditches and swales. The total vertical drop over the total segment length gives the slopes for each different segment. On the maps, time of concentration (Tc) segments are labeled with a length, a slope, and a flow type. Reach segments are labeled with a length and slope. The referenced maps are included as Sheets HY101-108 in Appendix A.

  Time of concentration for individual watersheds ranged from 1.3 minutes to 70.4 minutes.

Onsite Watersheds:

The area of interest in the watershed was divided into 78 separate subcatchments, ranging from 9,300 square feet to 5,360,000 square feet. Impervious characteristics ranged from 1% to 100% imperviousness. (See figure A-3 Subwatershed Identification and HY101-108.) 818 acres out of 5,652 total acres were represented in the stormwater models. Watershed boundaries were obtained from MDEP and adjusted by WBRC where necessary due to local topography observations. A spreadsheet of detailed watershed ground cover is included at the end of this section as table B8.

Twelve (12) "HYDROCAD" files were used to model the area of interest, with five (5) additional models representing proposed conditions. Several completed "HYDROCAD" files were obtained from contributing firms' archives and/or Bangor City Hall project files.

Stream Modeling Methods and Assumptions:

The stream channel was modeled using 19 descriptive reaches. The stream was approximated as a trapezoidal channel; dimensions were available from field data provided by Parish Geomorphic. Reach attributes are summarized in table B6 at the end of this section.

There are currently twelve (12) stream crossings. These include both culverts and bridges. See figure A-2 Stream Reach Identification in Appendix A for stream station attributes.

TABLE B3 – STREAM CROSSING LOCATIONS

CROSSING #	STATION	DESCRIPTION
1	0+000	Railroad
2	0+198	Route 2 - State St.
3	3+165	Mt. Hope Ave.
4	3+838	Evergreen Woods
5	5+245	BFCU
6	5+400	Hogan Road
7	6+222	New Sylvan Rd.
8	6+566	Old Sylvan Rd.
9	7+005	I-95
10	8+919	Bangor Mall Blvd.
11	10+111	Stillwater Ave.
12	12+171	Private drive

Due to the complexities of land coverage, marsh storage effects, beaver dam activity, and large wooded areas the upper Penjajawoc watershed, Meadow Brook tributary and Tributary #3 were not modeled and were instead each input as an assigned 2-year base flow value. These values were obtained from the companion reports, but were not based on actual logged stream values. We suggest that these values be contrived for future watershed management activity. A value of 7 cfs (cubic feet per second) was used for the base flow contribution from Penjajawoc Marsh entering the uppermost reach of the model. Calculated from data included in the Parish report, this number matched a value provided by ENSR in the SWMM study. Both tributaries were estimated to contribute 4 cfs. These estimates were intended to represent a dry season, such as August to September.

It was determined by use of the "upland" method that the peak time for the three large tributary subareas would lag the peak time of the developed area by between 5 and 10 hours. It was therefore determined that a base flow would be a more accurate representation for the purposes of this analysis. Actual stream conditions may include groundwater contributions and exfiltration. These were assumed to be accounted for in the assigned base flow.

Runoff rates for the 1-year, 2-year, 10-year, 25-year, 100-year and 500-year, Type III, 24-hour storm events for the hydrologic models are summarized in the following tables. Peak flows generated by the model were checked against projected flows obtained from the FEMA Flood Insurance Study, dated March 4, 2002. Flow landmarks for the 2-year storm event were furnished by Parish Geomorphic.

TABLE B4 – PEAK FLOW COMPARISONS (EXISTING CONDITIONS)

EVENT	MODEL PEAK (CFS)	LANDMARK PEAK (CFS)	VARIANCE (CFS)	%
1	269.91	--*	--	--
2	325.11	237	88	37%
10	610.08	510	100	20%
25	764.99	--*	--	--
100	971.31	1015	44	4%
500	1195.32	1555	360	23%

TABLE B5 – PEAK FLOW COMPARISONS (PROPOSED CONDITIONS)

EVENT	MODEL PEAK (CFS)	LANDMARK PEAK (CFS)	VARIANCE (CFS)	%
1	245.91	--*	--	--
2	302.41	237	65	27%
10	632.13	510	122	24%
25	798.74	--*	--	--
100	1019.24	1015	4	0.4%
500	1243.17	1555	312	20%

* No data available

TABLE B6 – STREAM REACH GEOMETRY USED IN HYDROCAD MODEL

PARISH Reach	Reach #	Stations Start/End	Bottom width (ft)	Channel depth (ft)	L/R side slope (ft/ft)	Length (ft)	n	Inlet/Outlet invert (ft)	Slope (ft/ft)	Base Flow (cfs)	Flood depth (ft)
	R0	0+102/0+198	12	5	2	96	0.05	9/8	0.0104	0	--
PS1	R1	0+253/0+945	12	3.5	3.4/4.3	692	0.04	20/15	0.0072	4	--
	R2	0+945/1+969	12	3.5	3.4/4.3	1024	0.04	32/20	0.0117	0	--
	R3	1+969/2+369	12	3.5	3.4/4.3	400	0.04	34/32	0.005	0	--
	R4	2+369/3+165	12	3.5	3.4/4.3	796	0.04	37/34	0.0038	0	--
PS2	R5	3+213/3+838	12	3.5	3.4/4.3	625	0.04	40.03/39.30	0.0012	4	--
	R6	3+887/4+809	12	3.5	3.4/4.3	922	0.04	45/41	0.0043	0	--
	R7	4+809/5+246	12	3.5	3.4/4.3	437	0.04	51/45	0.0137	0	--
PS3	R8	5+315/5+400	19	5.5	3.5/3.1	85	0.04	53.75/53.25	0.0059	0	--
	R9	5+509/6+222	19	5.5	3.5/3.1	713	0.04	62/55	0.0098	0	--
	R10	6+316/6+566	11	5.25	1.5/1.3	250	0.04	64/63	0.0004	0	--
PS4	R11	6+665/7+005	11	5.25	1.5/1.3	340	0.04	69/68.75	0.0007	0	--
	R13	7+420/8+188	19	5.5	3.5/3.1	768	0.04	72/70	0.0026	0	--
PS5	R14	8+188/8+919	19	5.5	3.5/3.1	731	0.04	77/72	0.0068	0	--
	R15	9+027/9+832	6	3	4.3/2.7	805	0.03	84/77	0.0087	0	--
PS6	R15A	9+832/10+111	6	3	4.3/2.7	279	0.03	86/84	0.0072	0	--
	R16A	10+196/10+888	6	3	4.3/2.7	692	0.03	95/88	0.0101	0	--
PS7	R16	10+888/12+121	6	3	4.3/2.7	1233	0.03	99/95	0.0032	0	--
PS8	R17	12+171/13+755	6	3	4.3/2.7	1584	0.03	105/101	0.0025	7	--

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Hydrocad Model Information:

TABLE B7 – NODE MATCHING

LINK #	GOES INTO:	FILE NAME	NODE TYPE	NODE #
318200 bmp retrofit design.hcp				
L2	R2	318200 ws 10-1900 combined.hcp	Subcat	100
L3	R3	318200 ws 10-1900 combined.hcp	Subcat	10
L4	R4	318200 ws 10-1900 combined.hcp	Pond	100-R
6L	P3	318200 ws 10-1900 combined.hcp	Subcat	11
L5	P4	318200 ws 10-1900 combined.hcp	Reach	300-R
1L	R6	318200 ws 10-1900 combined.hcp	Reach	320-R2
L7	R6	318200 ws 10-1900 combined.hcp	Subcat	200
L8	P5	318200 ws 10-1900 combined.hcp	Reach	200-R
L9	P6	318200 EMCC Master Plan (Future 2) All.hcp	Reach	21R
L10	R9	291010-POST_DEVELOPED darling honda.hcp	Reach	25R
2L	P7	318200 ws 10-1900 combined.hcp	Subcat	1300
L11	P8	318200 ws 10-1900 combined.hcp	Reach	1700-R
3L	P8	318200 ws 10-1900 combined.hcp	Subcat	400
4L	R11	318200 ws 10-1900 combined.hcp	Reach	600-R
L14B	P9	318200 wS 2900,2700,2510,2300,2100.hcp	Reach	0
L12	P9	318200 ws 10-1900 combined.hcp	Subcat	800
L13B	P9	318200 1000series.hcp	Reach	0
L13	R13	318200 1000series.hcp	Reach	1000-R
L14	R13	318200 bangor mall 2550.hcp	Reach	24R
L15	P10	318200 1200series,1400SERIES.hcp	Reach	1200-R
L17	R15	318200 1200series,1400SERIES.hcp	Reach	1200-R4
9L	P11	318200 1200series,1400SERIES.hcp	Reach	0
L16B	P11	318200 wS 2900,2700,2510,2300,2100.hcp	Reach	R0
L16	R16A	318200 wS 2900,2700,2510,2300,2100.hcp	Subcat	2900
5L	P12	318200 wS 2900,2700,2510,2300,2100.hcp	Subcat	2920
L19	P12	318200 ws 3100 JWSewall.hcp	Reach	R6
318200 ws 3100 JWSewall.hcp				
1L	R1B	318200 ws 3100 upstream.hcp	Pond	12
318200 1200series,1400SERIES.hcp				
8R	1297-P	target Gorrill-Palmer.hcp	Reach	8R
10R	1297-R	target Gorrill-Palmer.hcp	Reach	10R
POI4	1299-R	target Gorrill-Palmer.hcp	Subcat	4
POI55	1297-R2	target Gorrill-Palmer.hcp	Subcat	5

- <318200 bmp retrofit design.hcp> is the model of the main Penjajawoc Stream channel. It contains 60 nodes. This model contains no subcatchments; all inflow is linked from separate project files.

- <318200 tree diagram.hcp> is a Hydrocad file full of dummy nodes that show in which order the model files should be run.

- <318200 ws 10-1900 combined.hcp> is a Hydrocad file containing watersheds 10, 11, 100, 110, 200, 300, 310, 311, 320, 321, 322, 400, 410, 411, 412, 520, 600, 800, 1300, 1500, 1700, 1710, 1711, 1712, and 1900, along with 10 reaches and 6 ponds, for a total of 41 nodes.

- <318200 wS 2900,2700,2510,2300,2100.hcp> is a Hydrocad file containing watersheds 2100, 2300, 2510, 2511, 2512, 2513, 2514, 2700, 2710, 2720, 2730, 2740, 2750, 2900, 2910, and 2920, along with 7 reaches and 4 ponds, for a total of 27 nodes.

- <318200 1000series.hcp> is a Hydrocad file containing watersheds 1000, 1010, 1030, 1040, 1090, 1091, 1092, 1093, 1220, some parts of watershed 1091 that were described with 6 nodes by CES, 6 reaches, and 7 ponds for a total of 28 nodes.

- <318200 EMCC Master Plan (Future 2) All.hcp> is a Hydrocad file that was modeled by WBRC for a different project. It was inserted into the area entitled watershed 500. This plan contains 70 nodes. Watershed 500 is also modeled in part by the file <291010-POST_DEVELOPED darling honda.hcp>. This file, also made previously by WBRC, is of Darling's Honda on Sylvan Rd. It contains 48 nodes.

- <318200 bangor mall 2550.hcp> is a Hydrocad file that was made in 1998 by WBRC. It is of the Bangor Mall, contained in watershed 2550. Added to this file for completeness' sake was watershed 2500. It contains 83 nodes.

- <318200 ws 3100 JWSewall.hcp> is a file of an unbuilt development contained in watershed 3110. It was obtained from J.W. Sewall and the model was linked into the project. It contains 67 nodes.

- <318200 ws 3100 upstream.hcp> is a Hydrocad file containing watersheds 3130, 3140, 3150, 3160, and 3120. Watershed 3120 was modeled by CES. This file has 42 nodes, mostly from CES. This project links into Sewall's model of the Widewaters development.

- <target Gorrill-Palmer.hcp> is a model of the Target development from Gorrill-Palmer. It contains 23 nodes and connects into model <318200

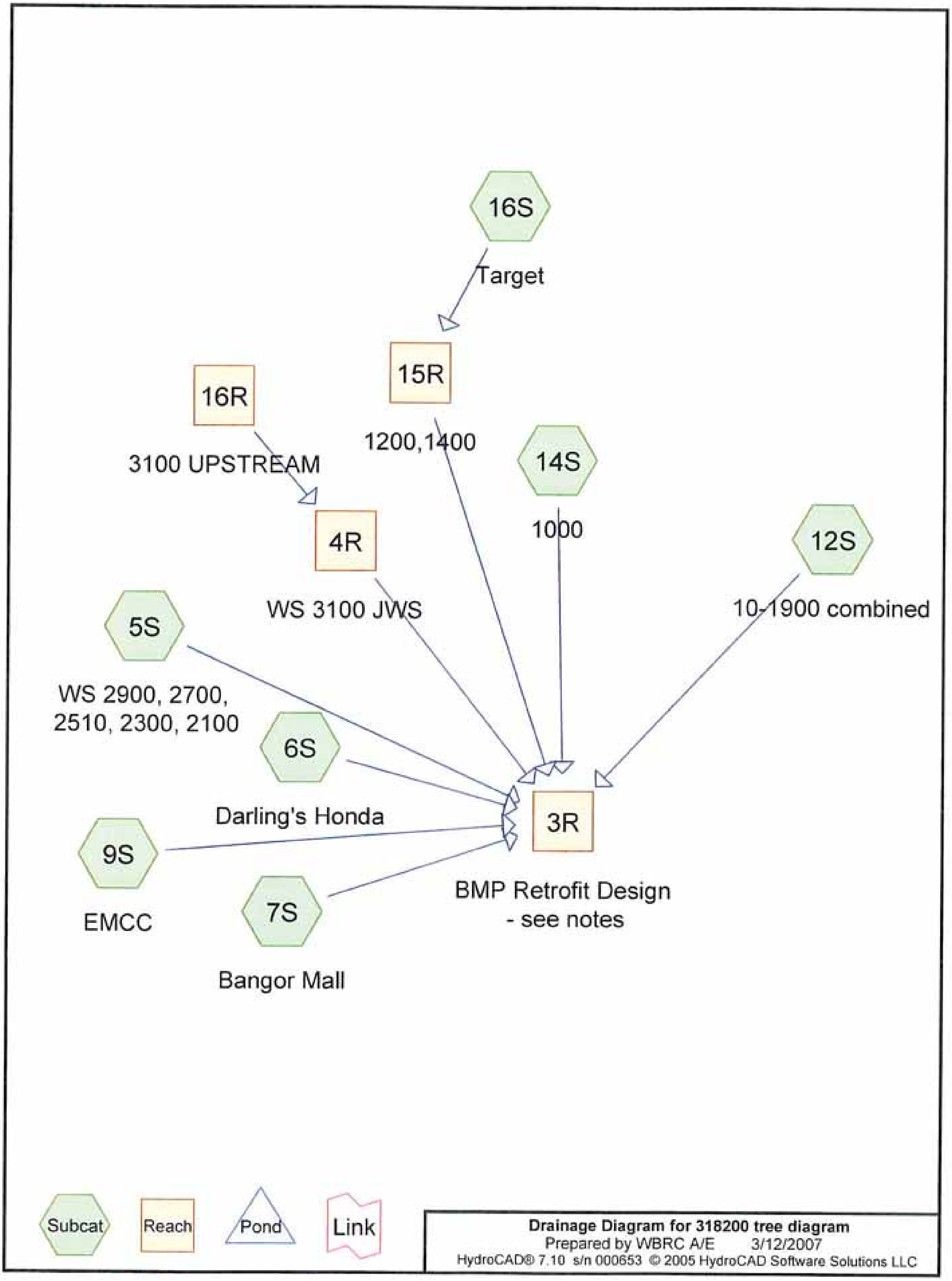
1200series,1400SERIES.hcp>. Some parts of this model do not drain into the Penjajawoc watershed. These outflows were discarded and the areas were not tallied.

- <318200 1200series,1400SERIES.hcp> is a Hydrocad file containing watersheds 1200, 1210, 1230, 1240, 1270, 1280, 1290, 1291, 1293, 1294, 1296, 1297, 1298, 1299, 1410, 1410B, 1412, 1413, and 1420. Also contained are 22 reaches, 12 ponds, and 4 links. The links are attached to the model for Target, which is contained in watershed 1292. This model has 58 nodes.

TABLE B8 SUBWATERSHED ATTRIBUTES

#	WBRC WS #	ENSR #	AREA (SF) Total	ACRES Total	Pervious area by hydrologic soil group (sf) A	B	C	D	Imperv	% IMP	CN	Tc (min)	Tc (hr)	Flow length (ft)	Desc
1	10	10	1,664,653	38.22	3,141	133,270	1,506,682	0	21,560	1%	71	55.2	0.9	1,683	
2	11	11	364,111	8.36	0	0	317,551	0	46,560	13%	77	46.7	0.8	1,344	
3	100	100, 101	2,174,579	49.92	0	1,141,895	775,729	0	256,955	12%	68	65.4	1.1	1,500	
4	110	110	659,829	15.15	0	0	393,559	0	266,270	40%	84	36.1	0.6	1,524	
5	200	200	445,698	10.23	0	0	325,860	0	119,838	27%	80	27.1	0.5	1,025	BFCU
6	300	300, 301	517,065	11.87	0	0	378,454	0	138,611	27%	80	6.9	0.1	930	Evergreen Woods
7	310	310	418,537	9.61	0	63,793	0	0	354,744	85%	92	4.1	0.1	1,220	Quirk
8	311	310	22,961	0.53	0	0	0	0	22,961	100%	98	2.5	0.0	453	Small section of Hogan Road
9	320	320	165,465	3.80	0	34,537	0	0	130,928	79%	90	3.3	0.1	546	Quirk
10	321	321	39,918	0.92	0	3,620	0	0	36,298	91%	95	1.5	0.0	120	Quirk
11	322	320	43,807	1.01	0	0	0	0	43,807	100%	98	4.3	0.1	1,136	Small section of Hogan Road
12	400	400, 401, 402	378,708	8.69	0	13,727	157,621	95,723	111,637	29%	82	7.9	0.1	754	Freeway
13	410	410	282,912	6.49	0	0	41,418	0	241,494	85%	94	5.1	0.1	610	Bangor Ford
14	411	410	73,869	1.70	0	0	12,115	0	61,754	84%	94	3.2	0.1	300	Bangor Dodge
15	412	410	238,609	5.48	0	0	79,070	74,415	85,124	36%	84	17.6	0.3	690	Gas station
16	500	500, 710, 700, 900	5,361,196	123.08					31.4 ac	26%					EMCC & Darling's Honda - **Note: modeled by WBRC
17	520	520	1,240,020	28.47	0	4,173	855,499	0	380,348	31%	81	67.4	1.1	1,880	United Technology Center
18	600	600	253,528	5.82	0	0	138,407	37,289	77,832	31%	82	13.4	0.2	1,065	Freeway
19	800	800	283,144	6.50	0	0	181,951	13,570	87,623	31%	82	49.3	0.8	1,925	Freeway
20	1000	1000	266,200	6.11	0	0	150,177	57,753	58,270	22%	78	3.2	0.1	535	Wendy's and stream banks
21	1010	1010	446,116	10.24	0	12,006	260,718	39,237	134,155	30%	81	19.2	0.3	2,020	Freeway
22	1030	1030	226,190	5.19	0	0	80,580	33,270	112,340	50%	89	3.0	0.1	546	Hampton Inn/99
23	1040	1040	440,128	10.10	0	1,061	116,802	0	322,265	73%	93	3.8	0.1	1,218	Toys R Us
24	1090	1090	114,274	2.62	0	0	24,357	0	89,917	79%	95	7.2	0.1	420	Lamey Wellehan etc.
25	1091	1091	432,426	9.93	0	97,048	20,090	0	260,778	60%	90	4.5	0.1	691	East side Hogan Rd - **Note: modeled in part by CES
26	1092	1090	530,228	12.17	0	26	114,656	2,612	412,934	78%	95	6.5	0.1	850	Kmart etc
27	1093	1090	307,234	7.05	0	9,327	39,228	8,564	250,115	81%	94	2.7	0.0	490	Maine Square Mall etc.
28	1200	1200	225,447	5.18	0	0	132,859	3,880	88,708	39%	84	3.4	0.1	403	Stream banks
29	1210	1210	58,481	1.34	0	0	12,653	0	45,828	78%	93	5.6	0.1	362	Arby's
30	1220	1220	199,735	4.59	0	0	46,374	0	153,361	77%	95	4.4	0.1	1,011	Best Buy
31	1230	1230	125,014	2.87	0	0	1,322	0	123,692	99%	98	4.5	0.1	597	Kmart etc
32	1240	1240, 1250	94,677	2.17	0	0	15,800	0	78,877	83%	94	2.7	0.0	257	Retail
33	1270	1270	70,426	1.62	0	0	19,792	0	50,634	72%	91	2.0	0.0	298	Retail
34	1280	1280	197,074	4.52	0	0	169,589	0	27,485	14%	77	2.0	0.0	267	Tributary banks
35	1290	1290	59,726	1.37	0	0	18,918	0	40,808	68%	90	3.8	0.1	514	Retail
36	1291	1291	161,591	3.71	0	0	46,079	0	115,512	71%	91	3.7	0.1	590	Inn and gas station
37	1292	1292	420,469	9.65					6.06 ac	63%					Target - **Note: modeled by Gorrill-Palmer
38	1293	1293	94,949	2.18	0	0	13,489	34,456	47,004	50%	88	1.9	0.0	418	VCOM
39	1294	1294	515,534	11.84	0	0	226,881	165,863	122,790	24%	82	4.7	0.1	773	Ridgewood
40	1296	1296	3,555,551	81.62	0	233,489	3,025,817	219,967	76,278	2%	72	70.4	1.2	3,210	Upper watershed
41	1297	1090	58,523	1.34	0	2,290	19,742	0	36,491	62%	88	2.1	0.0	345	Dunkin Donuts
42	1298	1090	42,992	0.99	0	0	33,918	0	9,074	21%	79	2.9	0.0	464	Retail
43	1299	1292	16,838	0.39	0	0	10,458	0	6,380	38%	83	3.4	0.1	373	Roadway section
44	1300	1300	65,263	1.50	0	0	30,501	26,644	8,118	12%	79	2.2	0.0	360	Sylvan Rd New
45	1410	1410, 1400	146,996	3.37	0	1,189	62,927	0	82,880	56%	87	2.4	0.0	609	Crossroads south
	1410B	1410, 1400	217,849	5.00	0	0	187,609	0	30,240	14%	77	13.1	0.2	519	Grassy area
46	1412	1411, 1412	192,021	4.41	0	36,204	18,996	38,957	97,864	51%	85	3.2	0.1	399	Crossroads north
47	1413	1420	230,509	5.29	0	21,694	107,112	10,762	90,941	39%	83	22.2	0.4	531	Inn
48	1420	1430	171,812	3.94	0	0	74,392	0	97,420	57%	88	3.9	0.1	198	Retail
49	1500	1500	203,809	4.68	0	0	60,874	25,826	117,109	57%	89	5.8	0.1	825	Parking lots
50	1700	1700	39,845	0.91	0	0	28,239	7,493	4,113	10%	78	1.7	0.0	290	Substation
51	1710	1710	289,909	6.66	0	0	223,992	15,719	50,198	17%	78	18.1	0.3	1,675	
52	1711	1100	481,780	11.06	0	49,571	353,662	15,338	63,209	13%	76	34.2	0.6	1,497	Rangely Hall and part of Sylvan Rd

#	WBRC WS #	ENSR #	AREA (SF)	ACRES	(sf)						CN	Tc	Tc	Flow length	Desc
			Total	Total	A	B	C	D	Imperv	% IMP		(min)	(hr)	(ft)	
53	1712	1100	522,935	12.00	0	0	260,776	84,533	177,626	34%	83	45.4	0.8	1,043	O. Sylvania
54	1900	1900	20,198	0.46	0	0	11,800	0	8,398	42%	84	12.1	0.2	480	
55	2100	2100	216,448	4.97	0	0	150,010	6,553	59,885	28%	81	12.1	0.2	1,464	
56	2300	2300	163,812	3.76	0	0	115,684	23,110	25,018	15%	79	7.2	0.1	859	
57	2500	2500	149,052	3.42	0	0	115,431	15,230	18,391	12%	78	2.5	0.0	517	
58	2510	2510	1,095,773	25.16	0	239,423	465,774	97,919	292,657	27%	78	23.5	0.4	2,251	Freeway
59	2511	2511	401,156	9.21	0	0	132,403	0	268,753	67%	90	2.9	0.0	855	Cinema
60	2512	2510	293,520	6.74	0	0	111,466	43,384	138,670	47%	86	8.2	0.1	1,240	Oriental Jade
61	2513	2510	322,098	7.39	0	0	163,791	145,179	13,128	4%	78	27.9	0.5	635	Lawn area
62	2514	2550	140,630	3.23	0	0	92,978	34,075	13,577	10%	78	13.2	0.2	756	Freeway
63	2550	2550	3,238,020	74.33					58.02 ac	78%					Bangor Mall - **Note: modeled by WBRC
64	2700	2700	177,722	4.08	0	0	110,430	176	67,116	38%	83	4.4	0.1	632	Goodwill store
65	2710	2700	15,077	0.35	0	0	771	33	14,273	95%	97	2.0	0.0	500	Small section of Stillwater Ave
66	2720	2550	72,292	1.66	0	0	19,914	0	52,378	72%	91	4.7	0.1	860	Happy China
67	2730	2550	49,064	1.13	0	0	7,485	0	41,579	85%	94	2.6	0.0	253	Sportshoe center
68	2740	2550	70,183	1.61	0	0	55,248	2,205	12,730	18%	79	40.8	0.7	353	Lawn area
69	2750	2550	255,567	5.87	0	0	173,823	41,938	39,806	16%	79	31.2	0.5	1,383	Mall lawn
70	2900	2900	347,314	7.97	0	0	191,484	0	155,830	45%	85	15.8	0.3	1,013	Penn Plaza
71	2910	2900	152,151	3.49	0	0	73,544	5,351	73,256	48%	86	2.0	0.0	367	Penn Plaza east
72	2920	3130	196,740	4.52	0	0	73,169	27,417	96,154	49%	87	4.6	0.1	1,067	JoAnn & golf store
73	3110	3110	1,891,468	43.42					19.11 ac	44%					Widewaters - **Note: modeled by JWSewall
74	3120	3120, 3122, 3121, 3123	242,558	5.57					4.08 ac	73%					The Avenue - **Note: modeled by CES
75	3130	3130	9,386	0.22	0	0	0	0	9,386	100%	98	1.3	0.0	328	Section of Stillwater Ave
76	3140	3130	51,128	1.17	0	0	9,913	14,011	27,204	53%	88	2.8	0.0	418	Talbot's
77	3150	3130	113,185	2.60	0	0	48,627	13,136	51,422	45%	86	21.5	0.4	705	Carpet One
78	3160	3130	157,658	3.62	0	0	104,304	0	53,354	34%	82	15.3	0.3	750	Building
	3100&1400	3100, 1400, 1600	150,867,031	3,463					1,508,670	1%					Penjajawoc Marsh - not modeled
	5000 series	5000 series, 1050, 1295	17,163,226	394					171,632	1%					Meadow Brook - not modeled
	--	1	42,510,603	976					425,106	1%					Cemetery - not modeled
		Modeled	35,693,360	819											
		Total	246,234,220	5,653											


16S
Target
15R
1200,1400
16R
3100 UPSTREAM
14S
1000
4R
WS 3100 JWS
12S
10-1900 combined
5S
WS 2900, 2700,
2510, 2300, 2100
6S
Darling's Honda
3R
9S
EMCC
7S
Bangor Mall
BMP Retrofit Design
- see notes
Subcat
Reach
Pond
Link
Drainage Diagram for 318200 tree diagram
Prepared by WBRC A/E 3/12/2007
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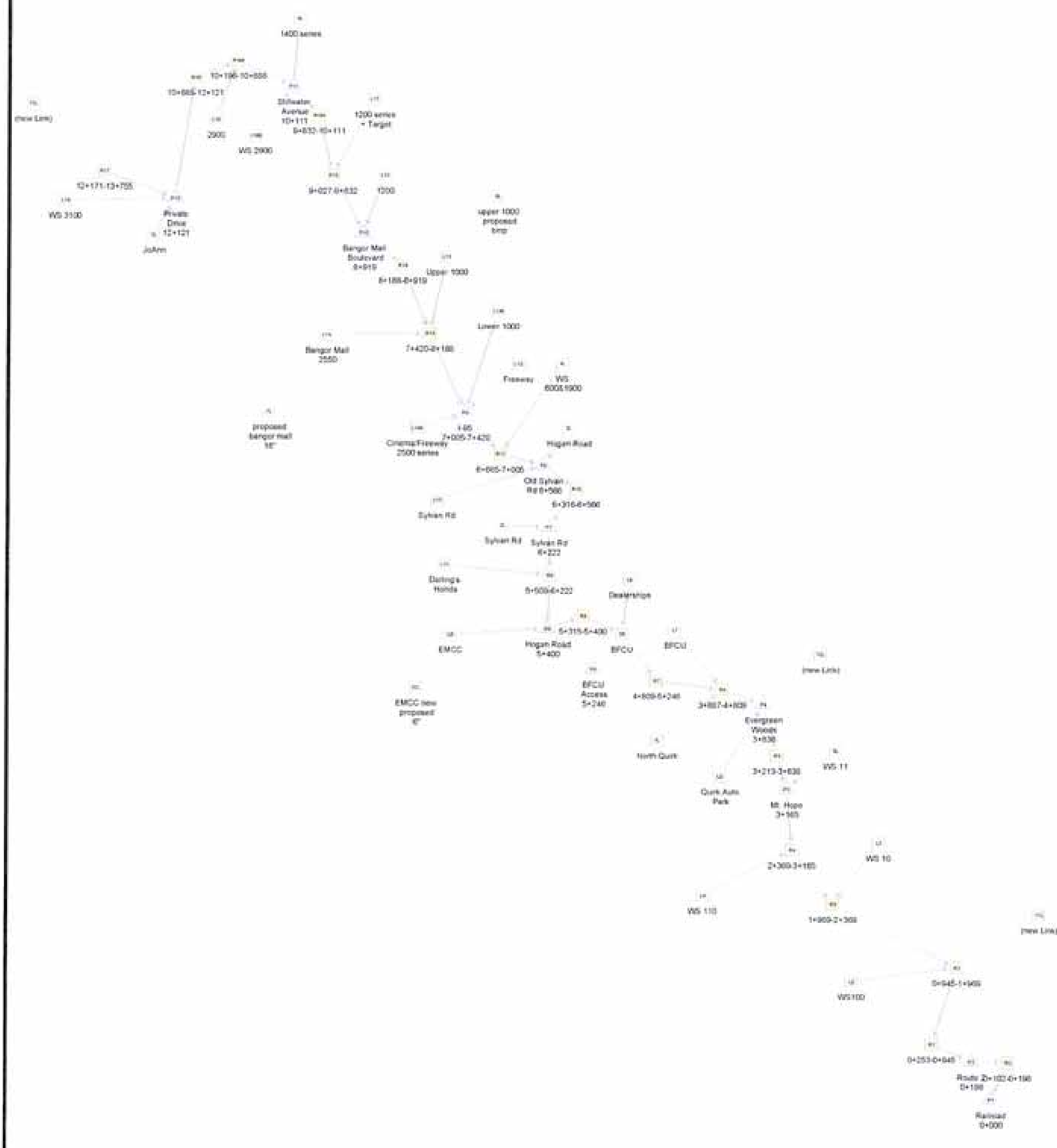

Drainage Diagram for 318200 bmp retrofit design
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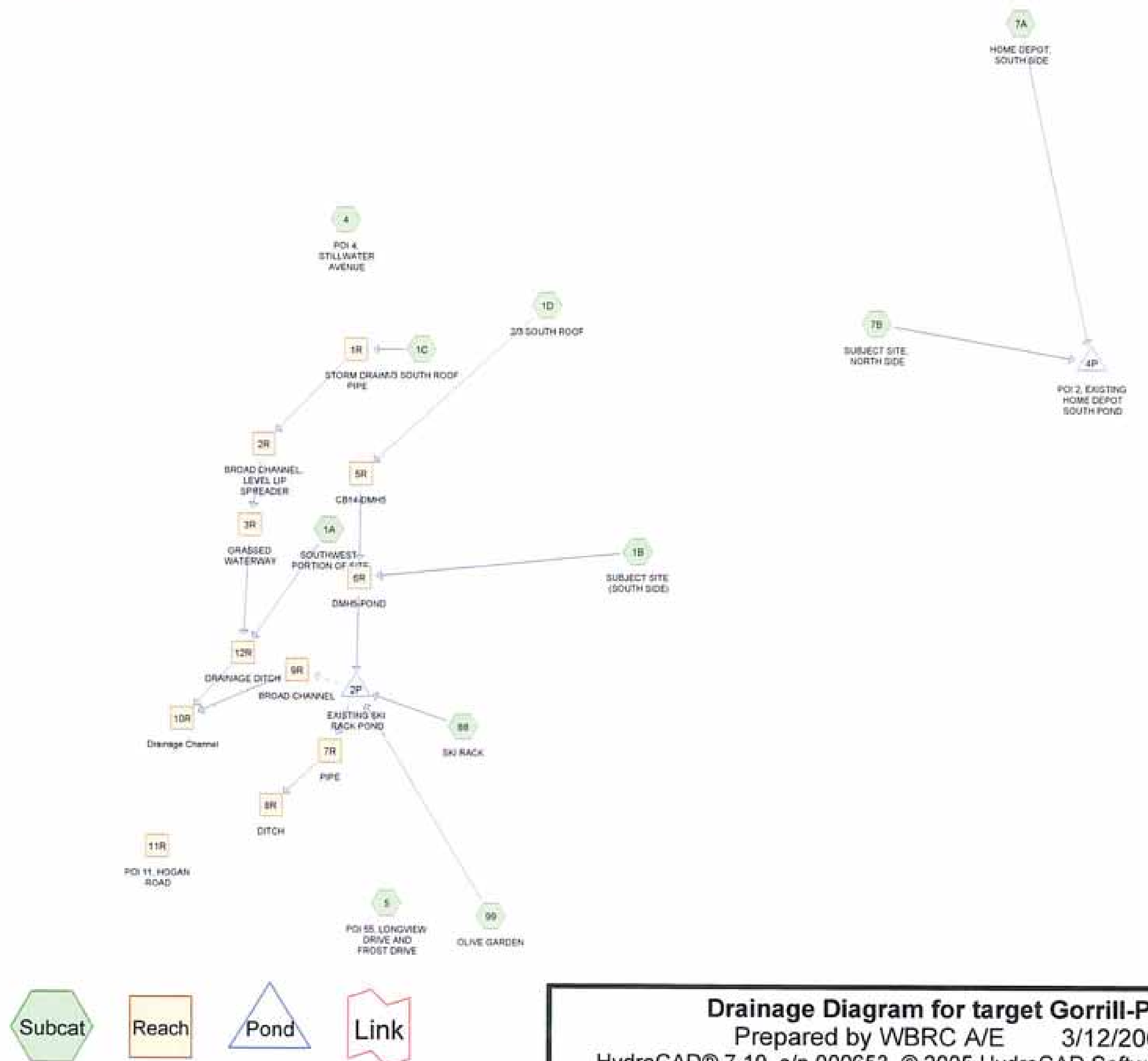

Drainage Diagram for target Gorrill-Palmer

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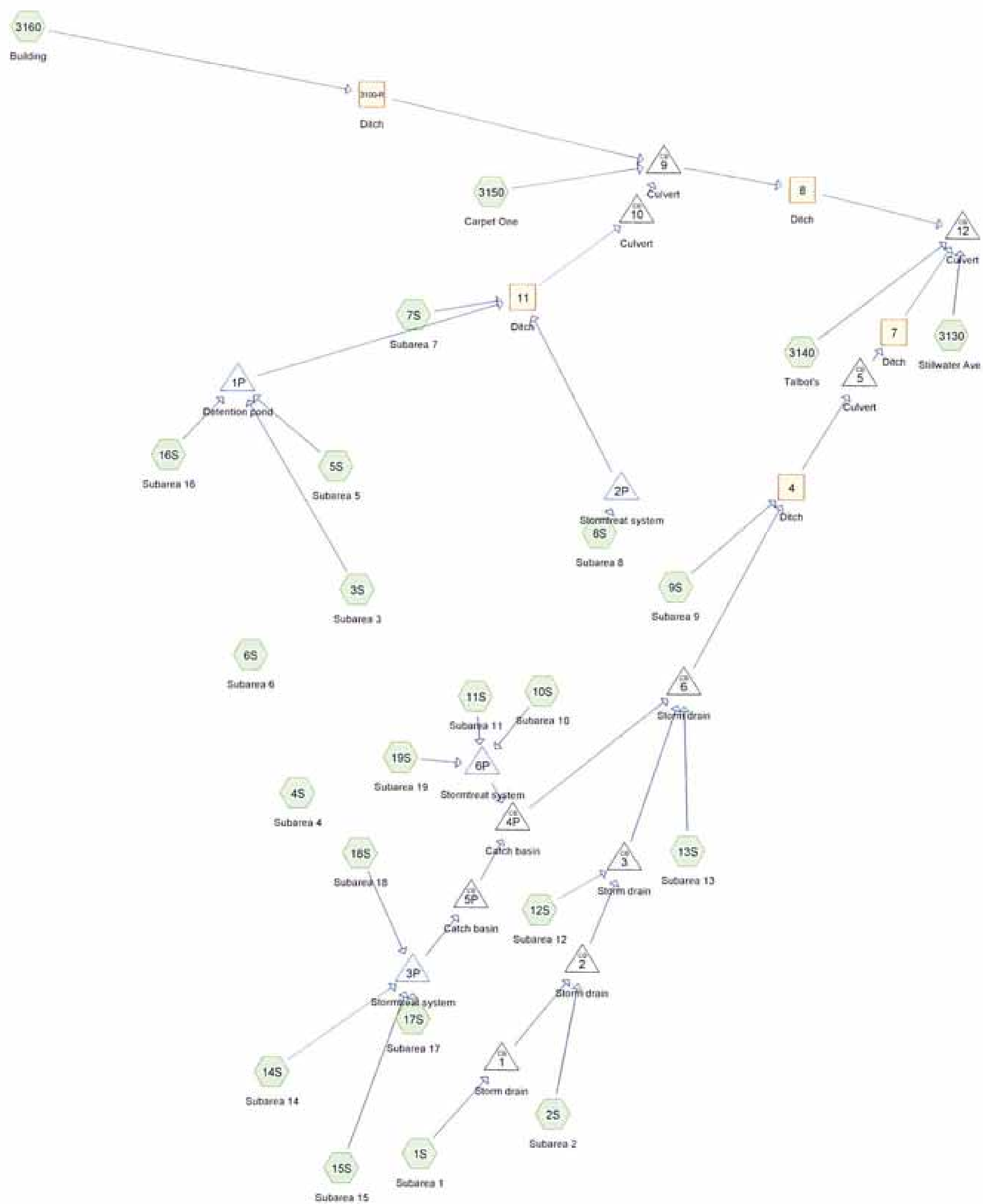

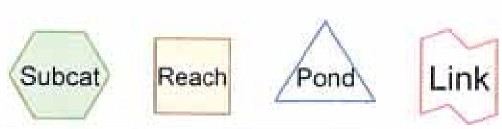

Drainage Diagram for 318200 ws 3100 upstream

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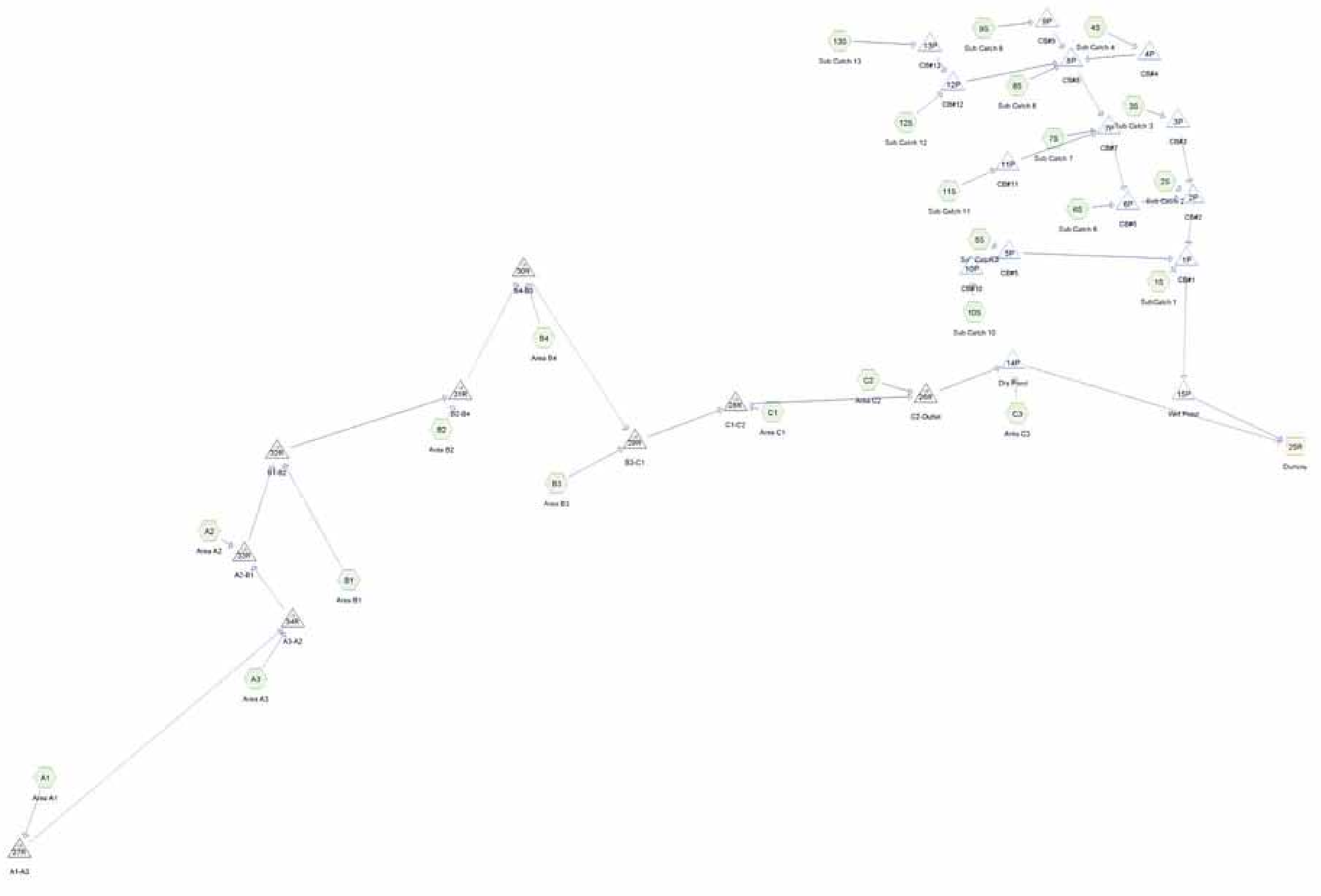

Drainage Diagram for 291010-POST_DEVELOPED darling honda
Prepared by WBRC A/E 3/12/2007
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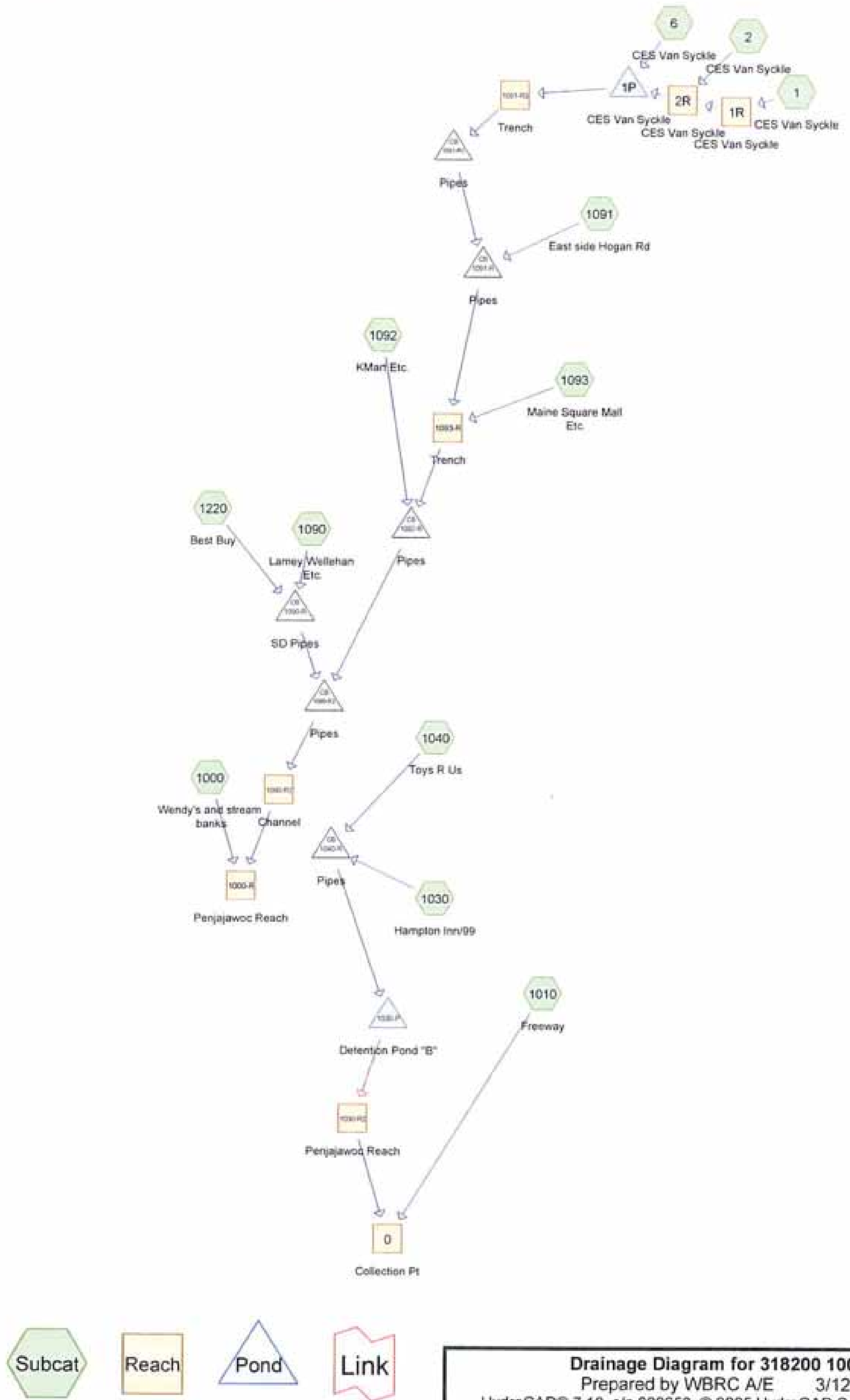

Drainage Diagram for 318200 1000series
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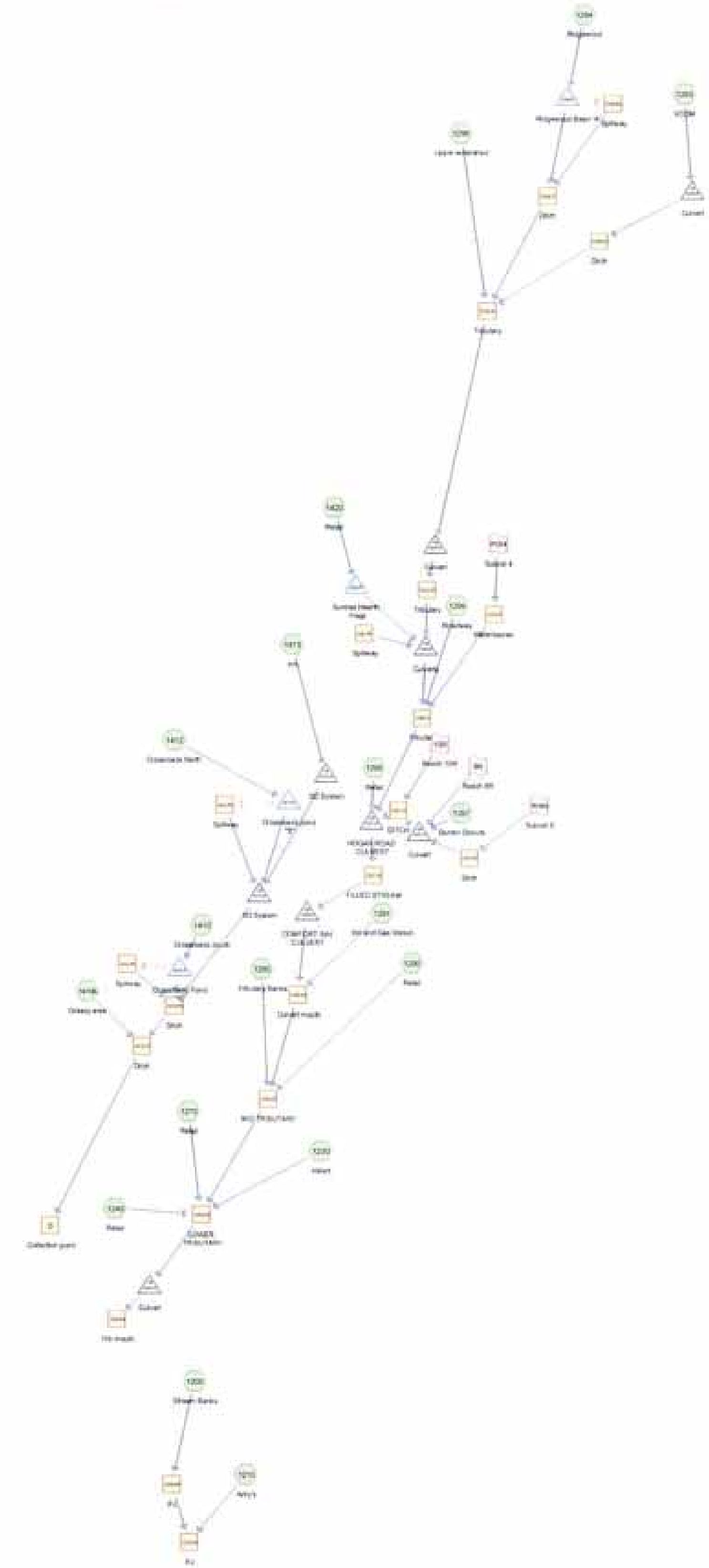

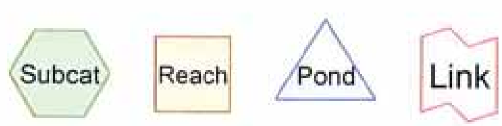

Drainage Diagram for 318200 1200series,1400SERIES
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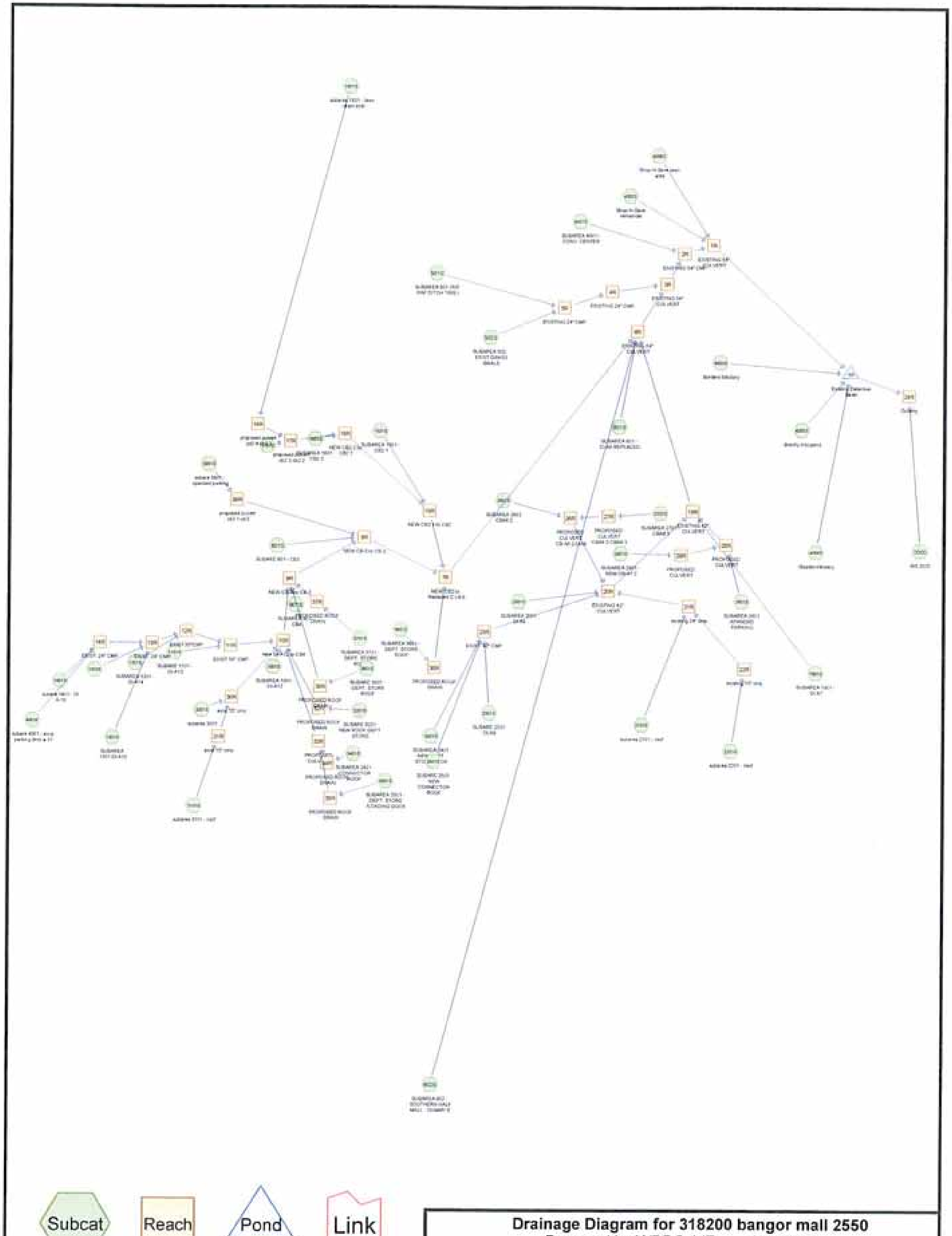

Drainage Diagram for 318200 bangor mall 2550
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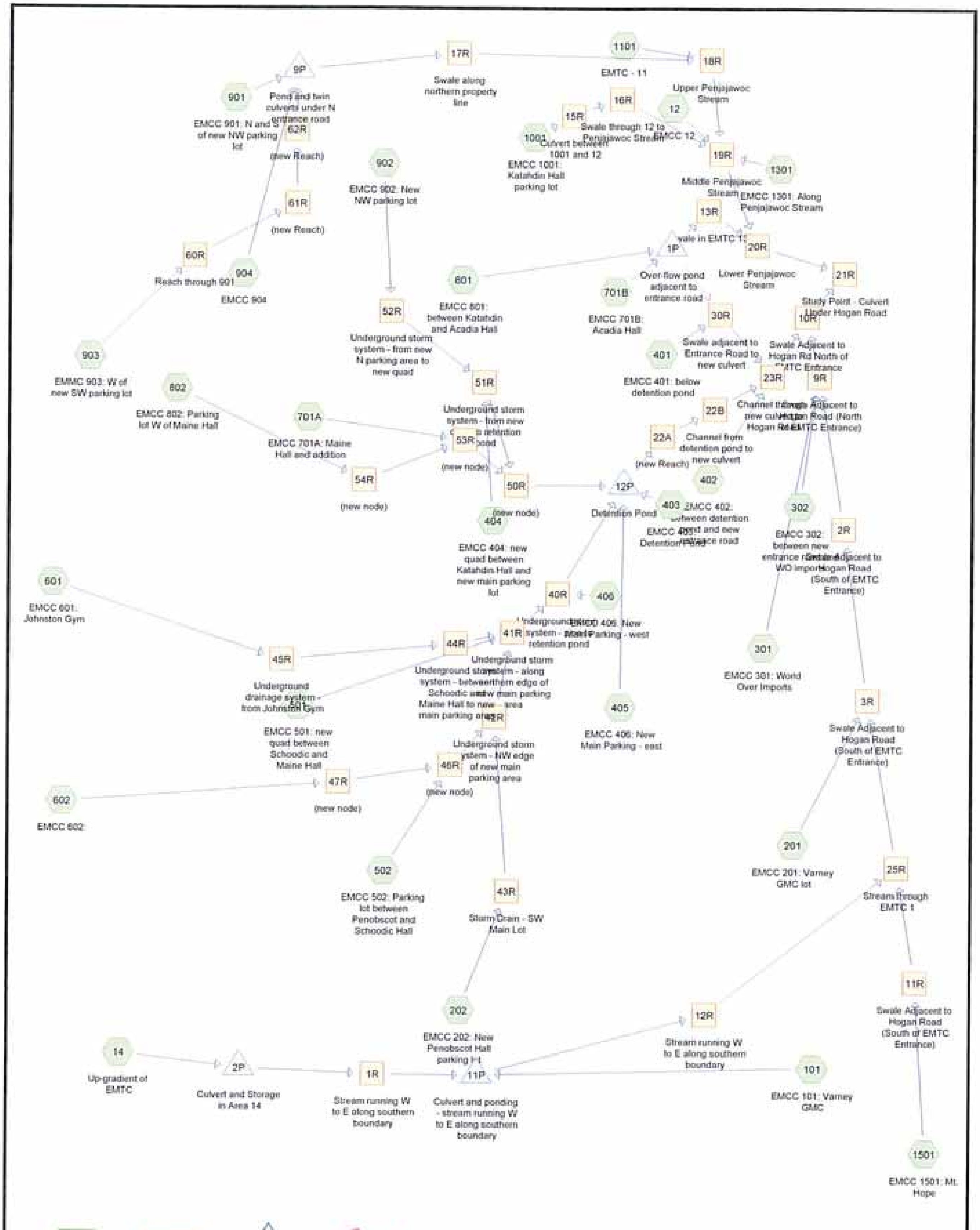

Drainage Diagram for 318200 EMCC Master Plan (Future 2) All

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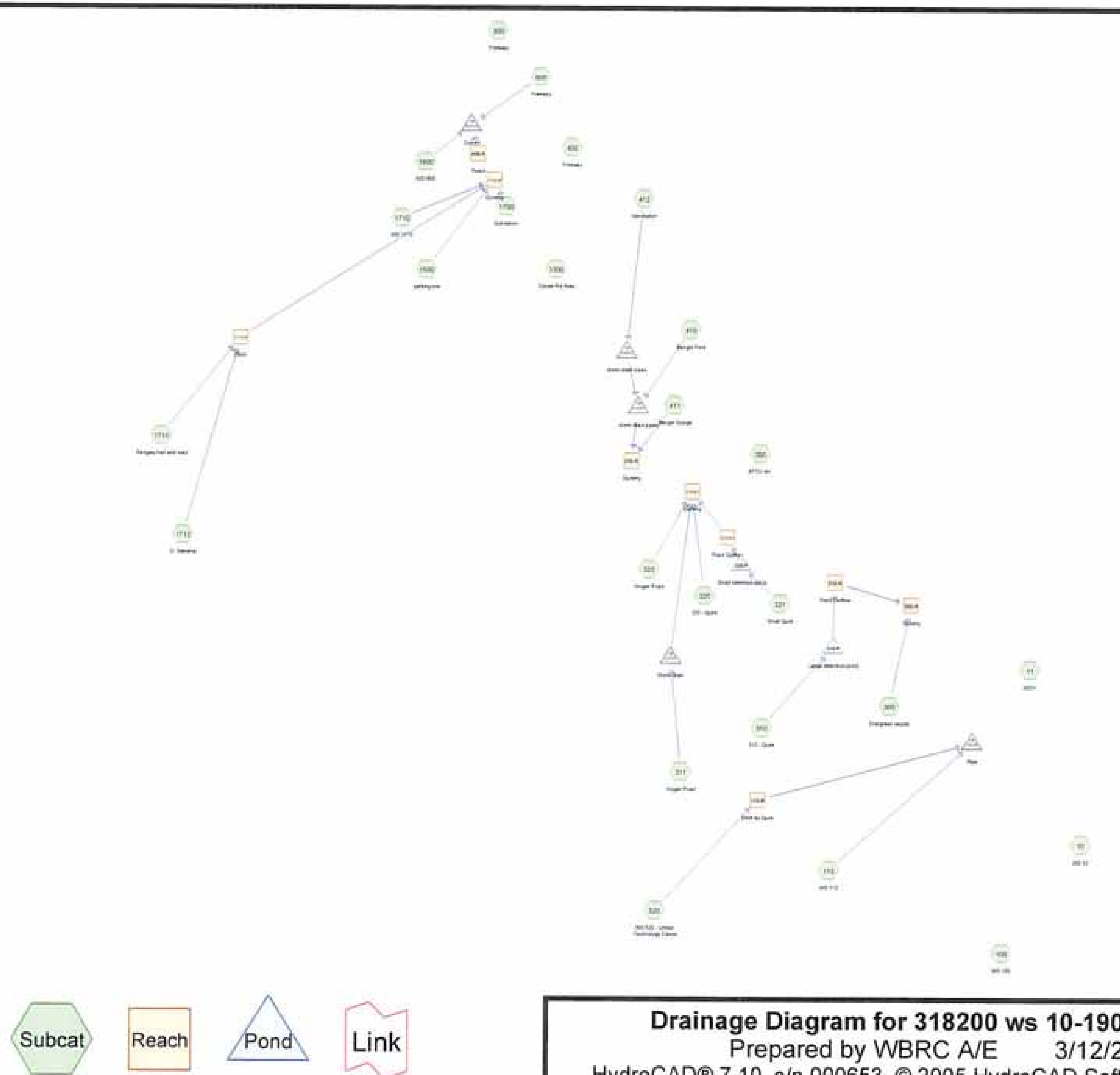

Drainage Diagram for 318200 ws 10-1900 combined
Prepared by WBRC A/E 3/12/2007
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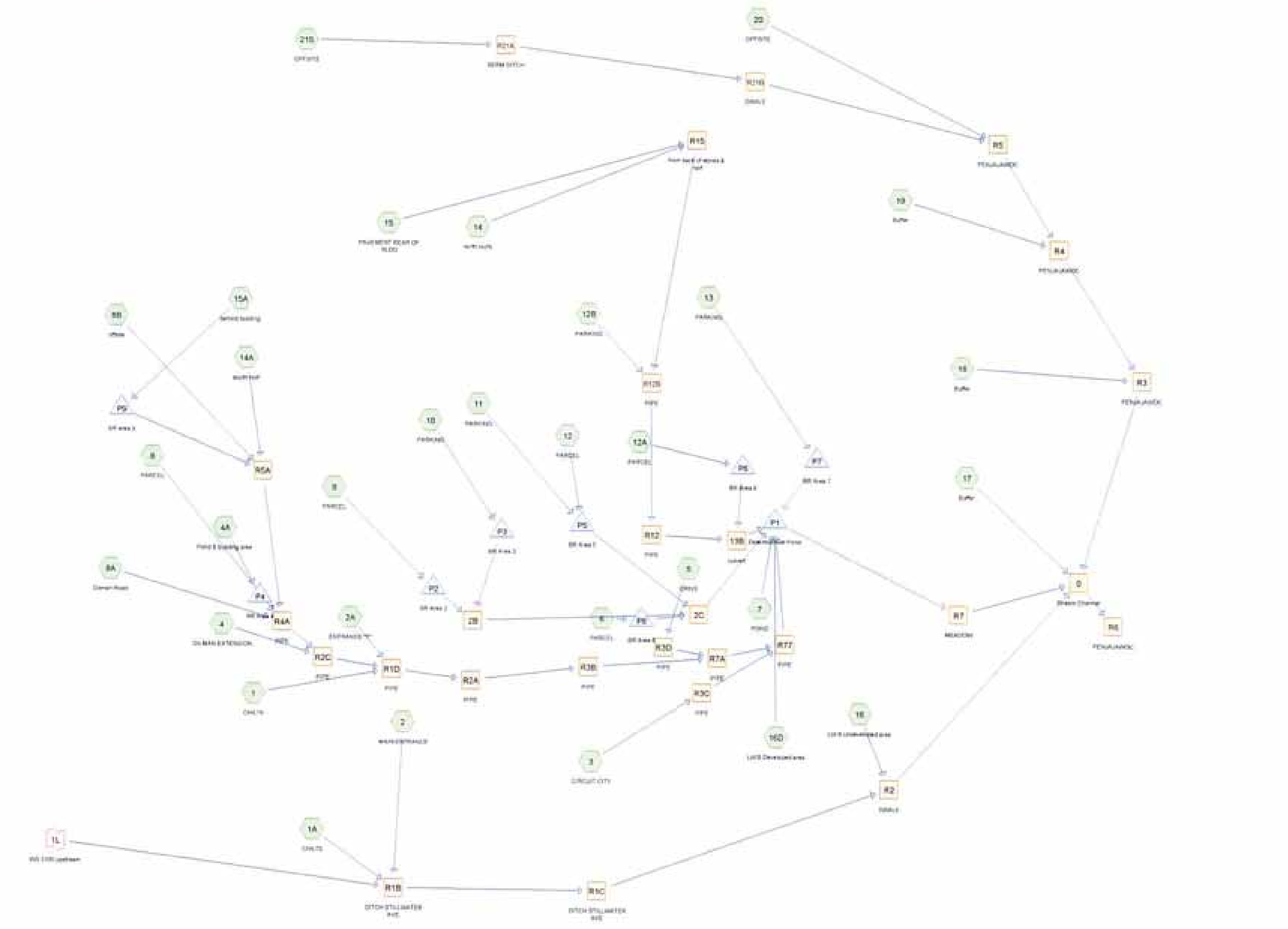

Drainage Diagram for 318200 ws 3100 JWSewall
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Appendix C –
Maine DEP Low Impact Development BMPs

WBRC
ARCHITECTS • ENGINEERS
Bangor, Maine and Sarasota, Florida

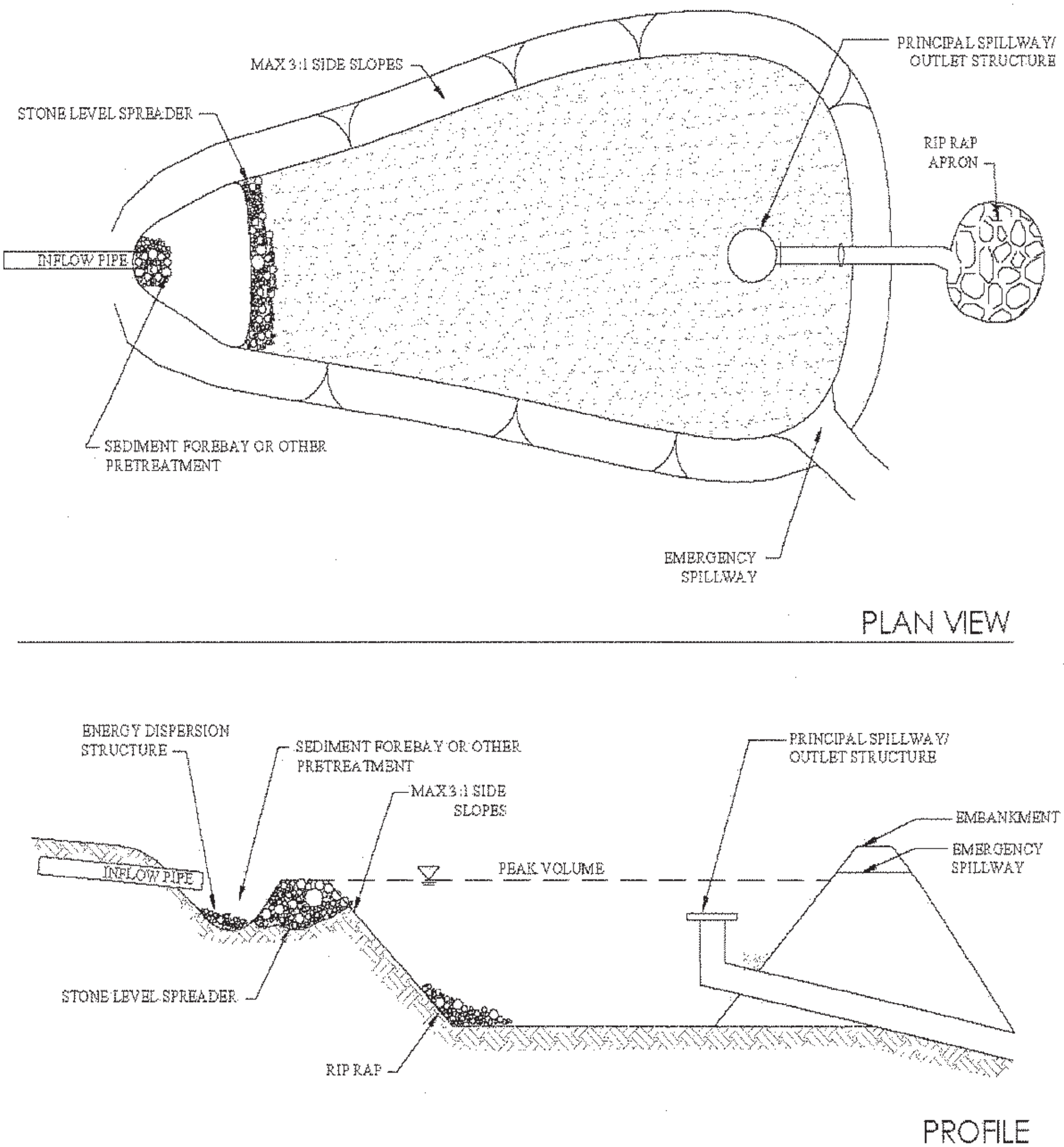


FIGURE 3-1. TYPICAL DETENTION BASIN

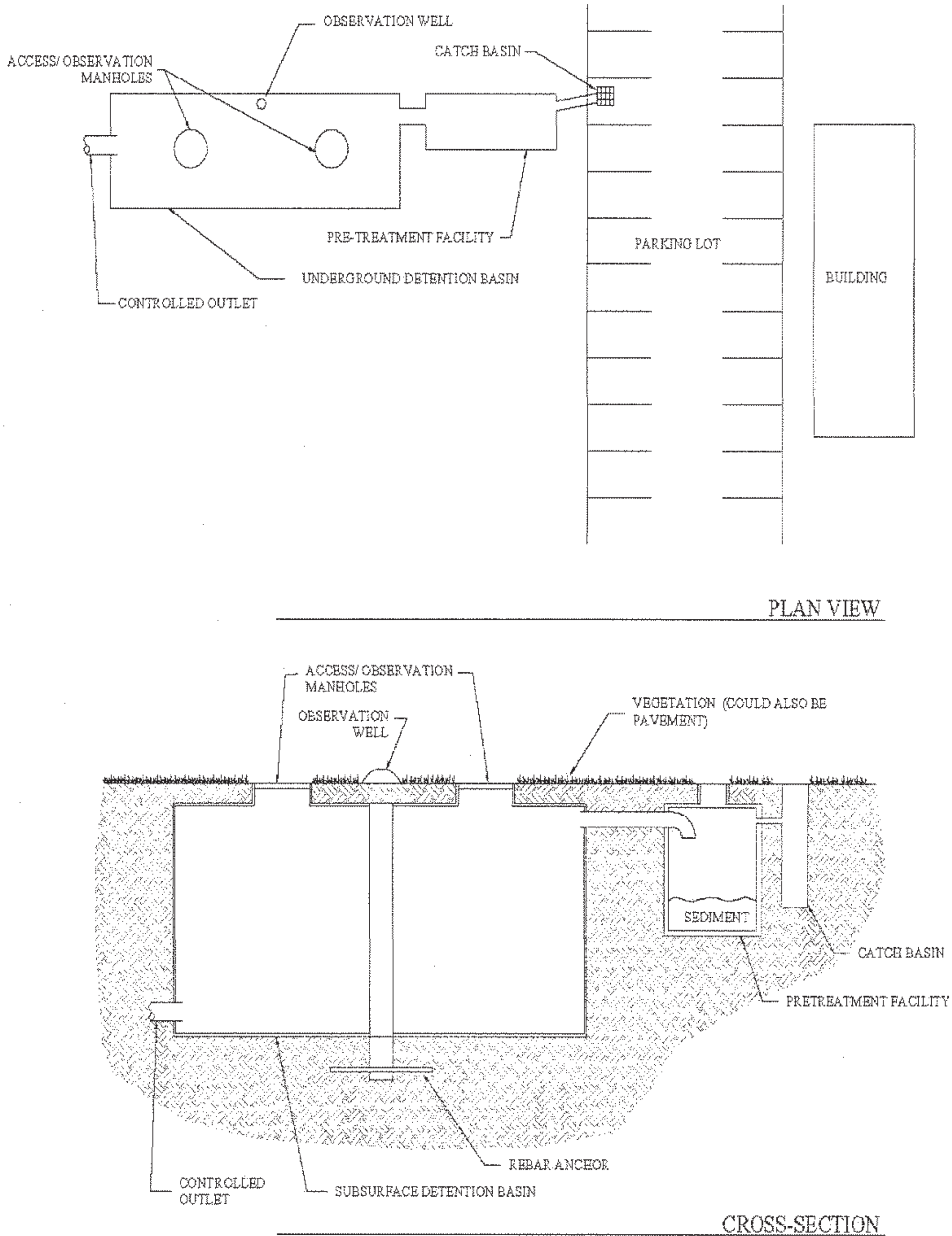
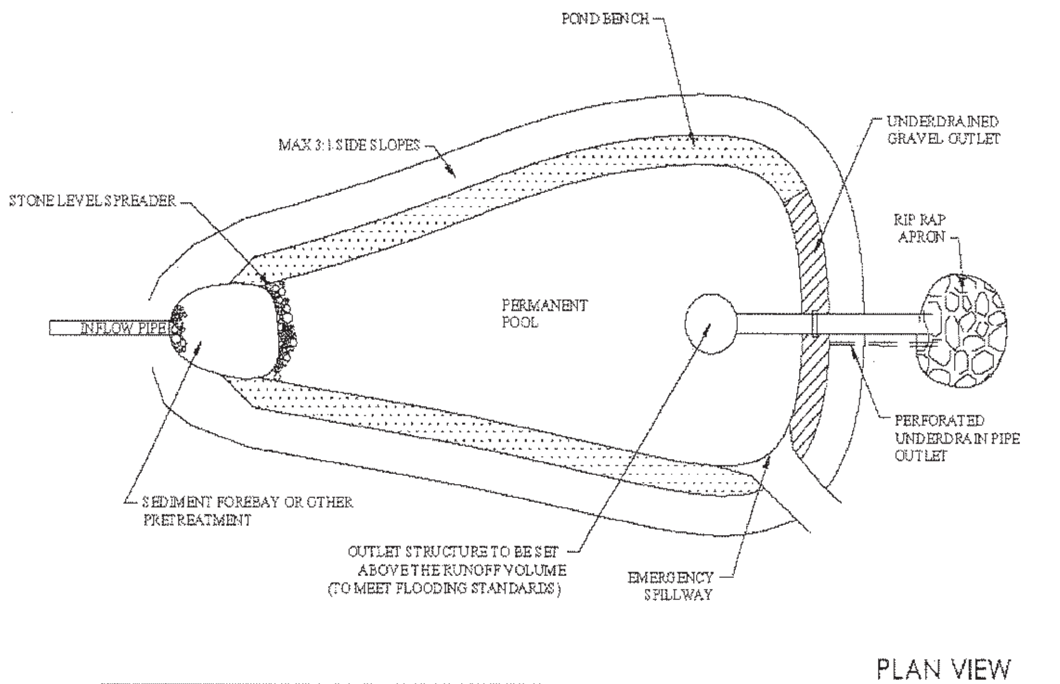


FIGURE 3-2. TYPICAL SUBSURFACE DETENTION BASIN



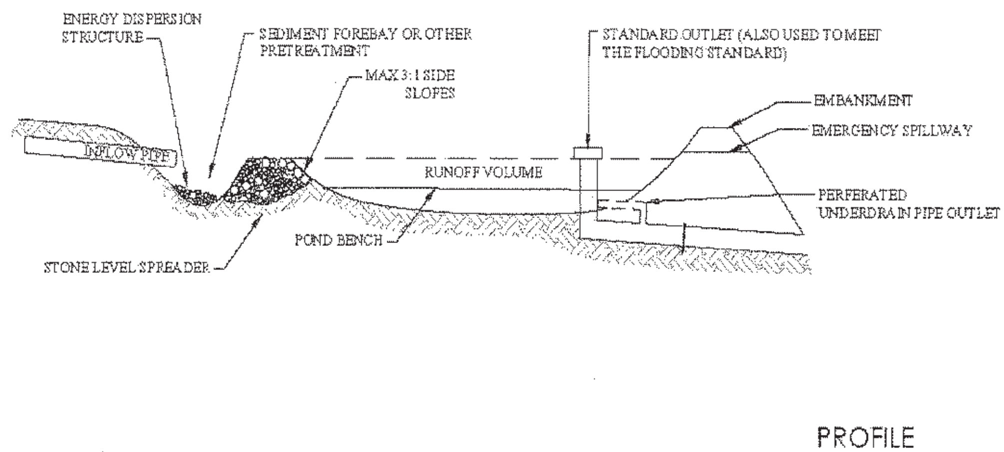


FIGURE 4-1. TYPICAL WET POND WITH UNDERDRAIN OUTLET

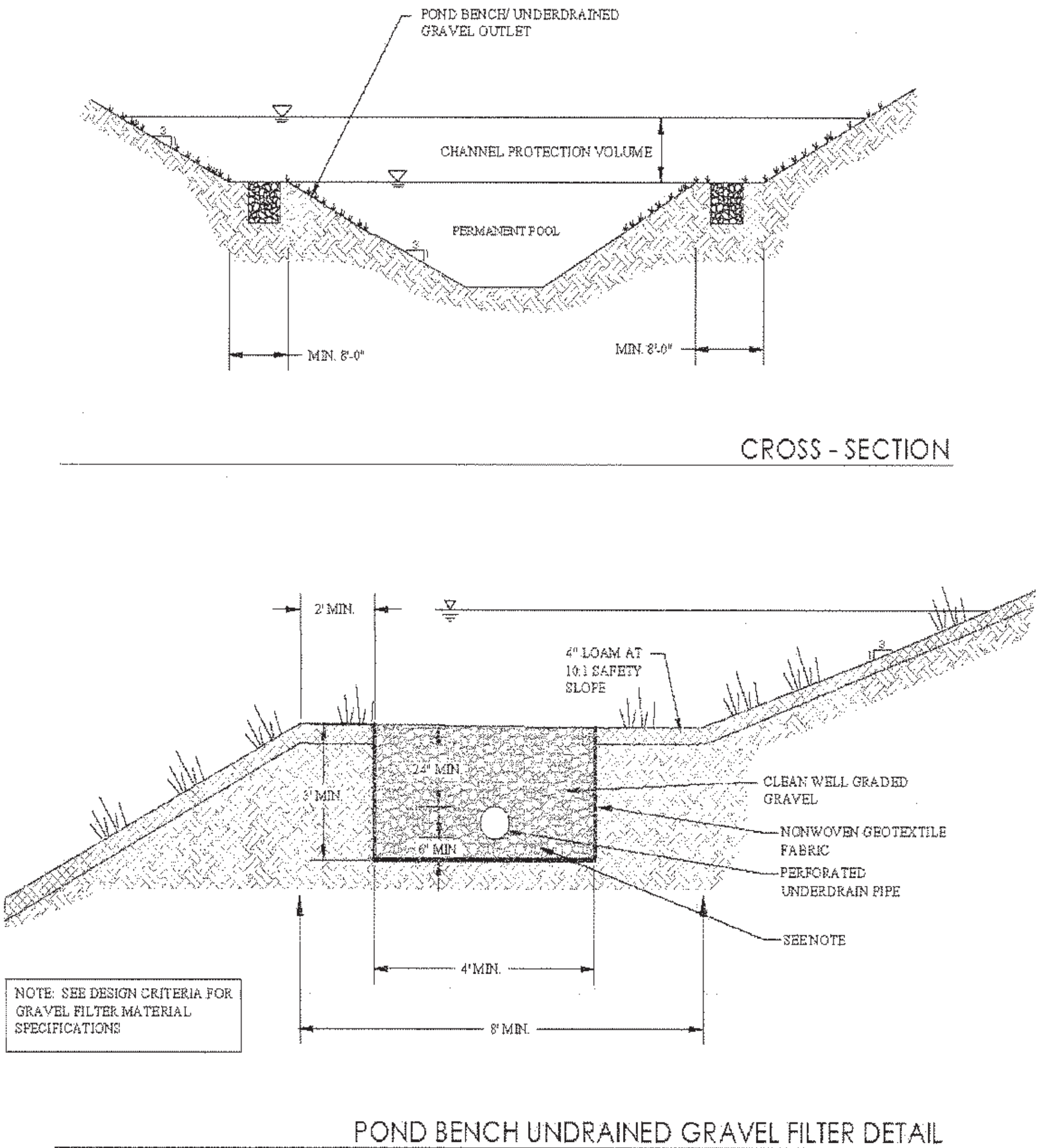


FIGURE 4-2. TYPICAL WET POND WITH UNDERDRAIN OUTLET

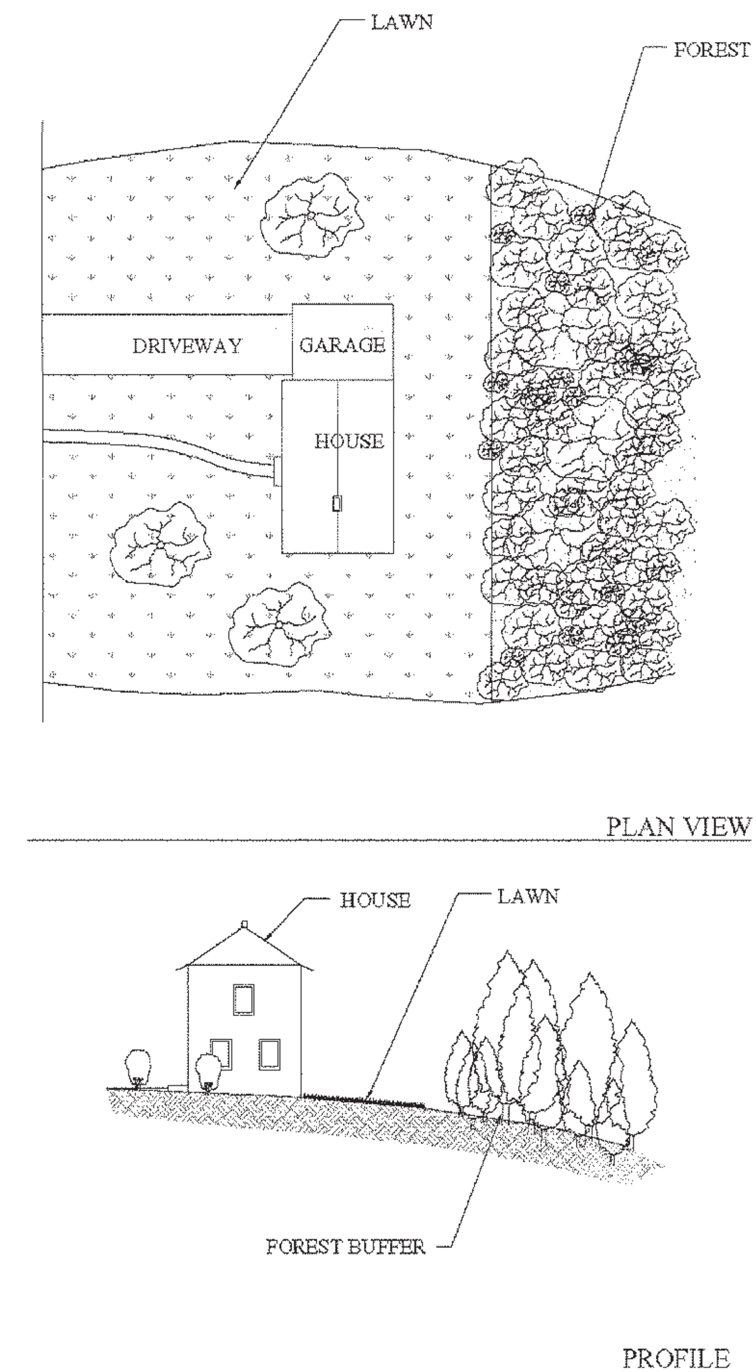


FIGURE 5-1. BUFFER ADJACENT TO RESIDENTIAL AREAS

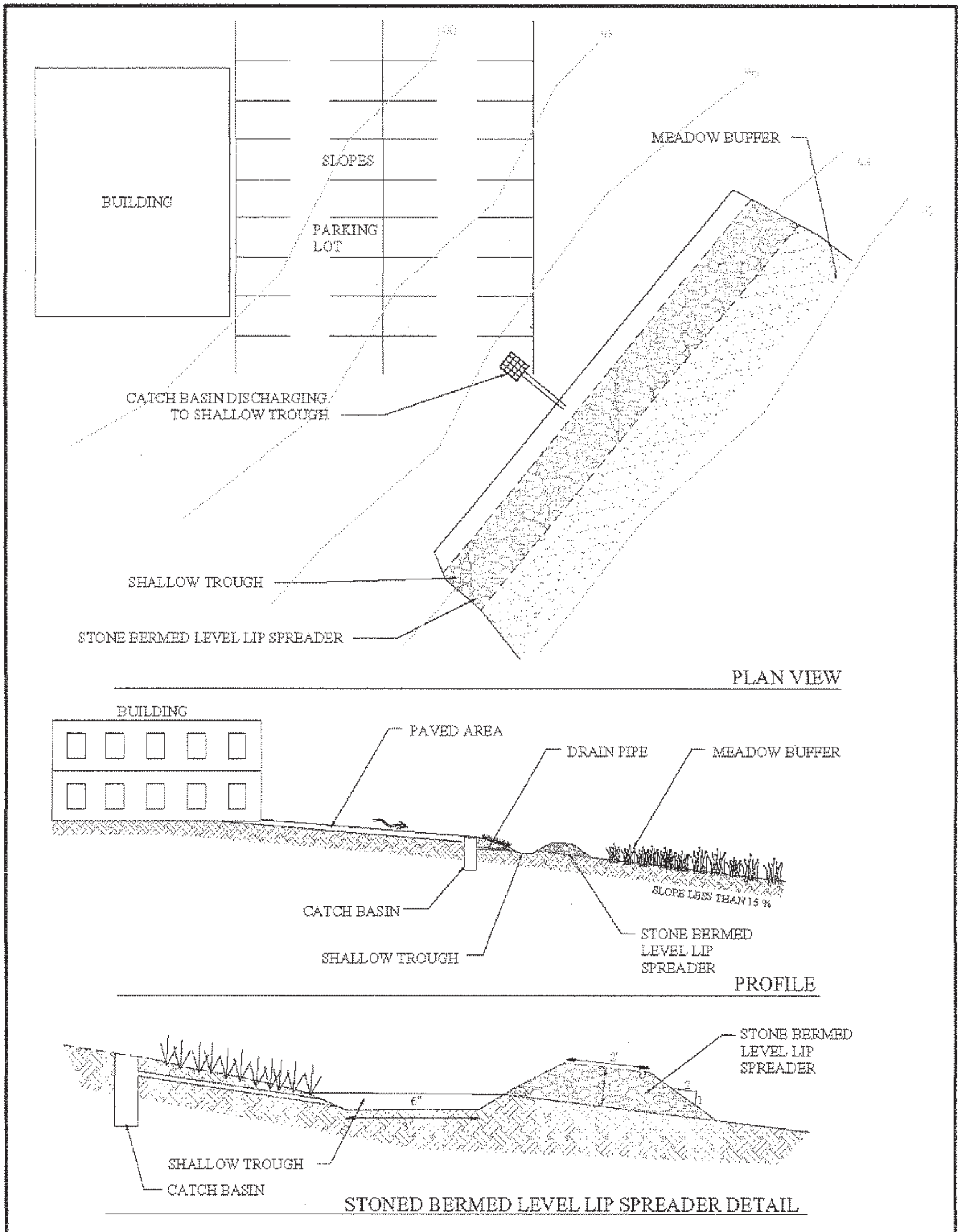


FIGURE 5-2. BUFFER WITH STONE BERMED LEVEL LIP SPREADER

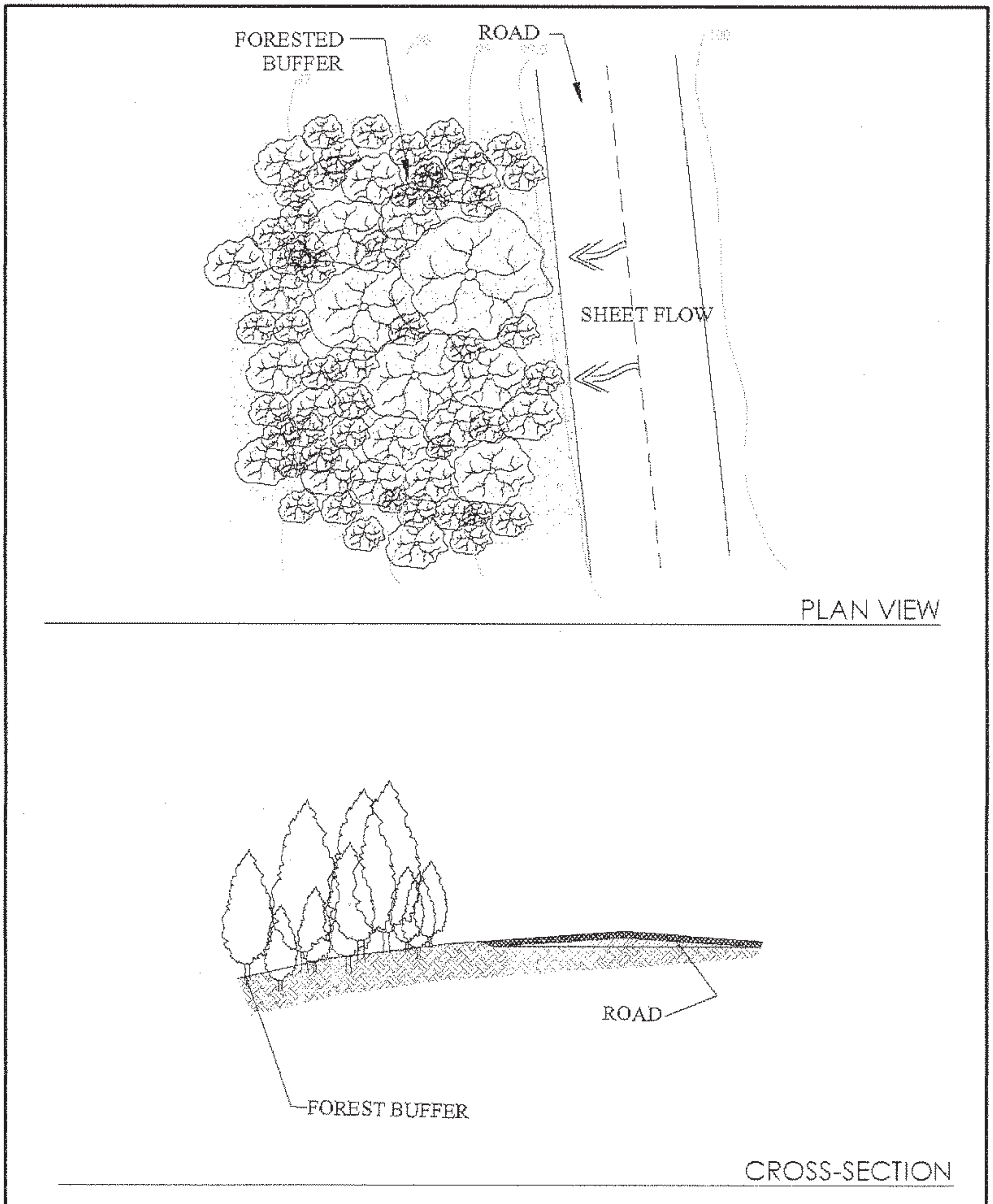


FIGURE 5-3. BUFFER ADJACENT TO THE DOWNHILL SIDE OF A ROAD

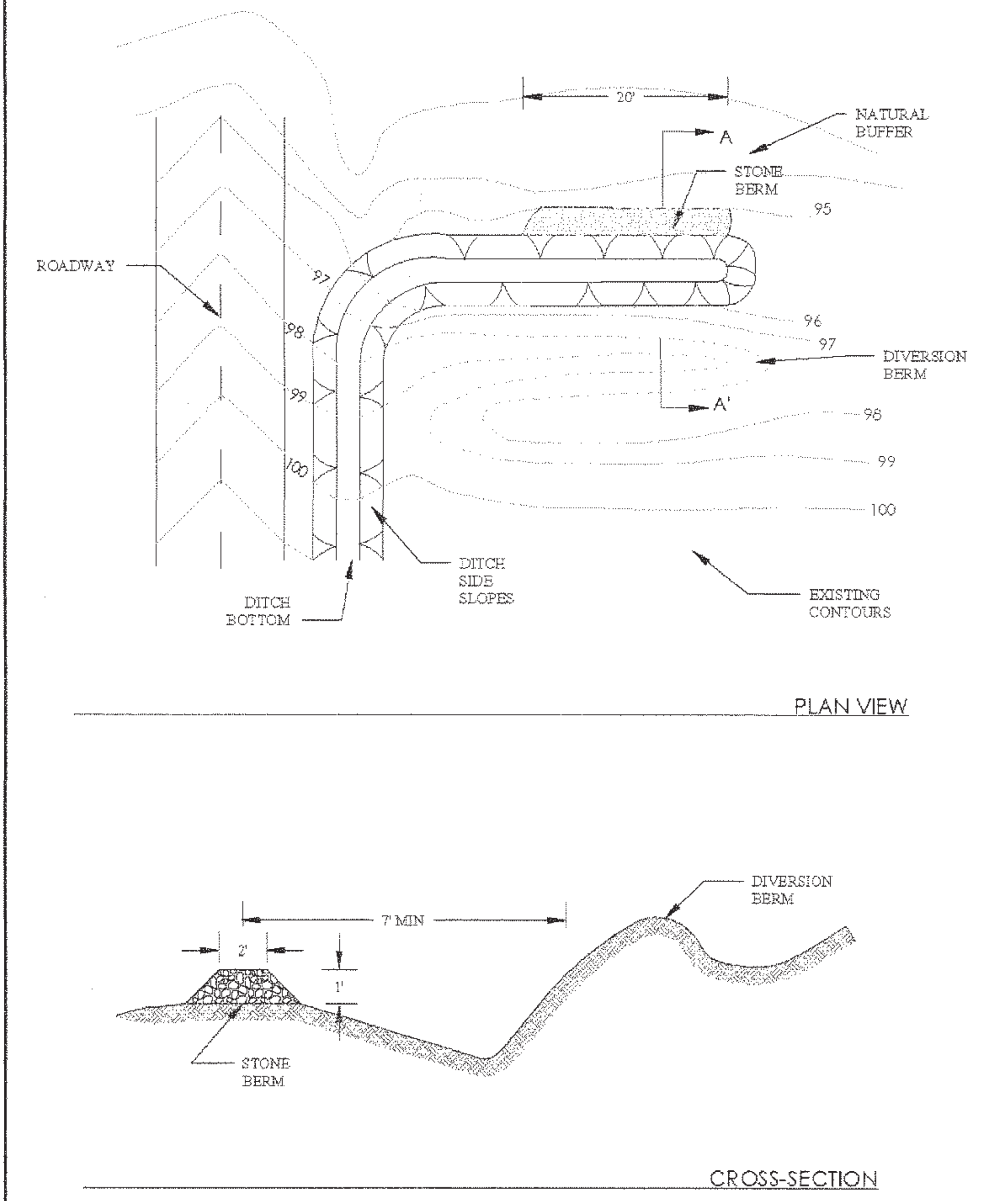


FIGURE 5-4. TYPICAL DITCH TURNOUT BUFFER

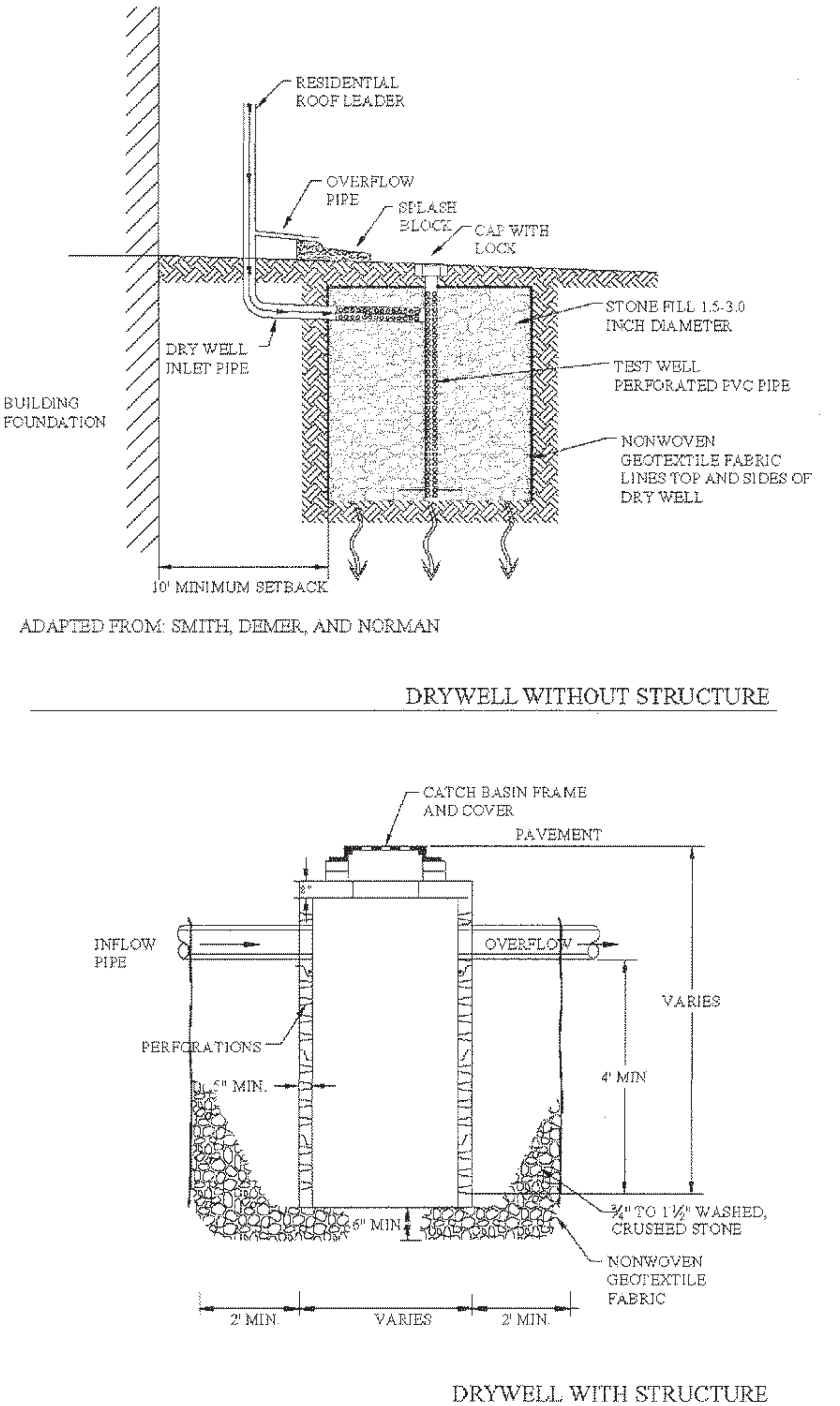


FIGURE 6-1. TYPICAL DRYWELL

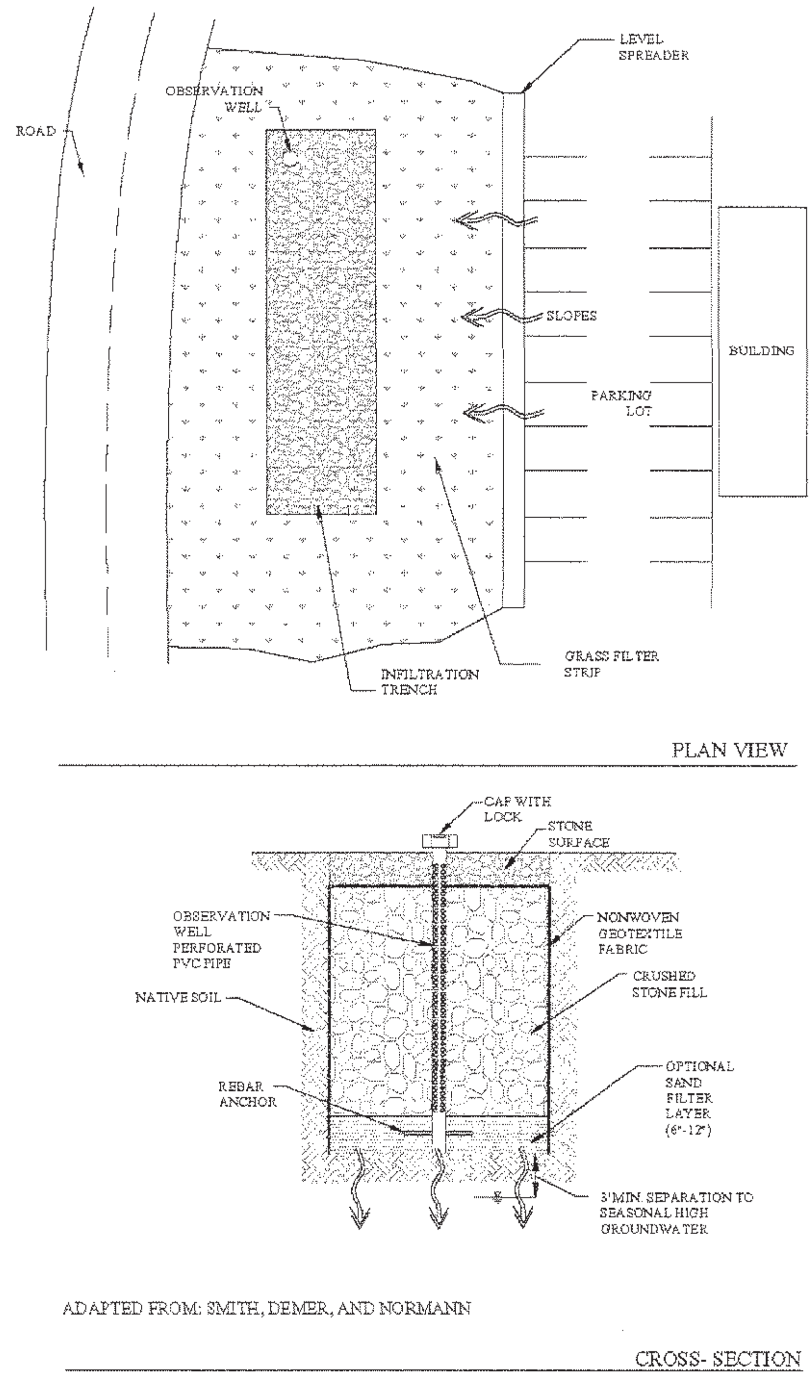


FIGURE 6-2. TYPICAL SURFACE INFILTRATION TRENCH

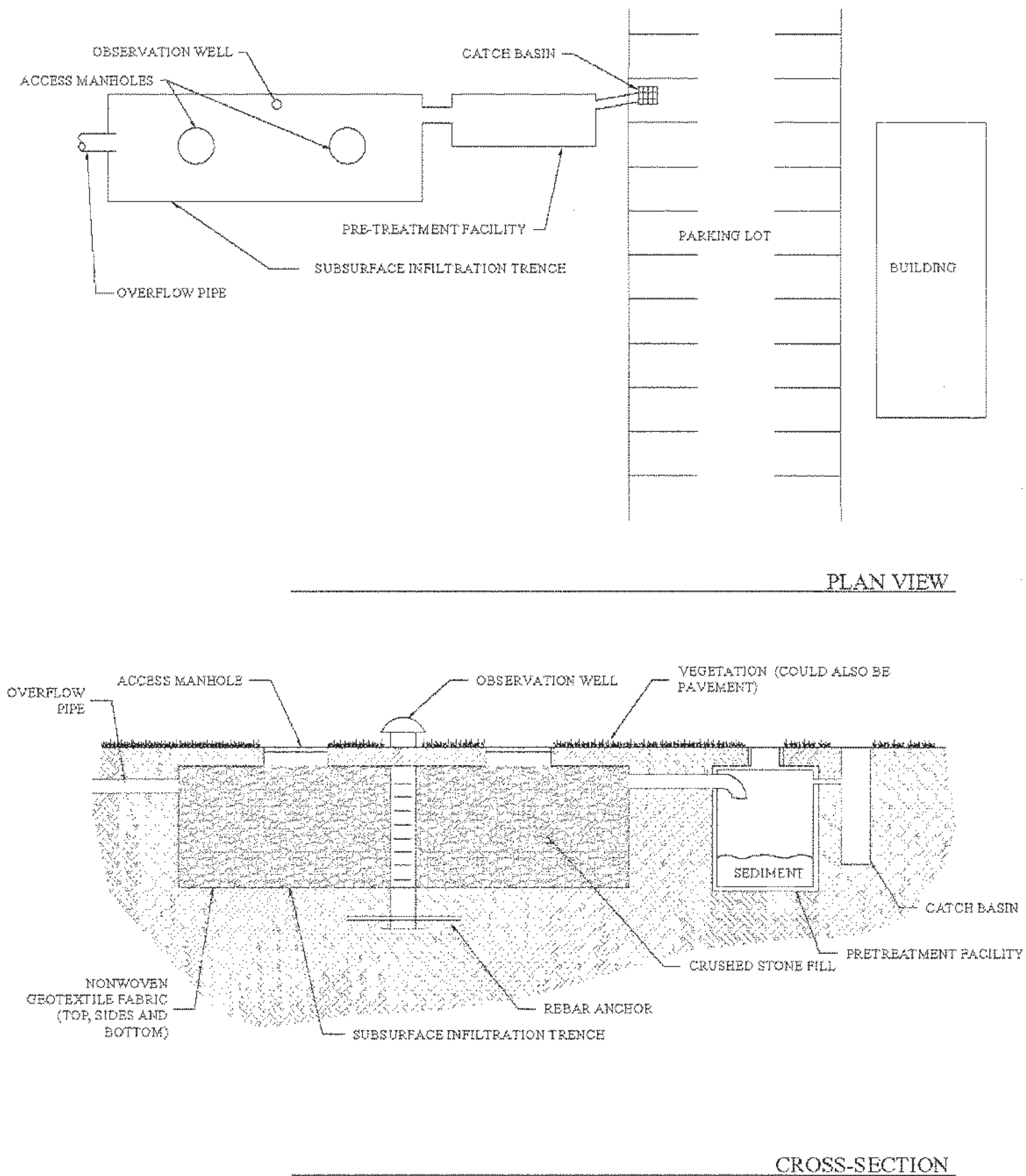


FIGURE 6-3. TYPICAL SUBSURFACE INFILTRATION TRENCH

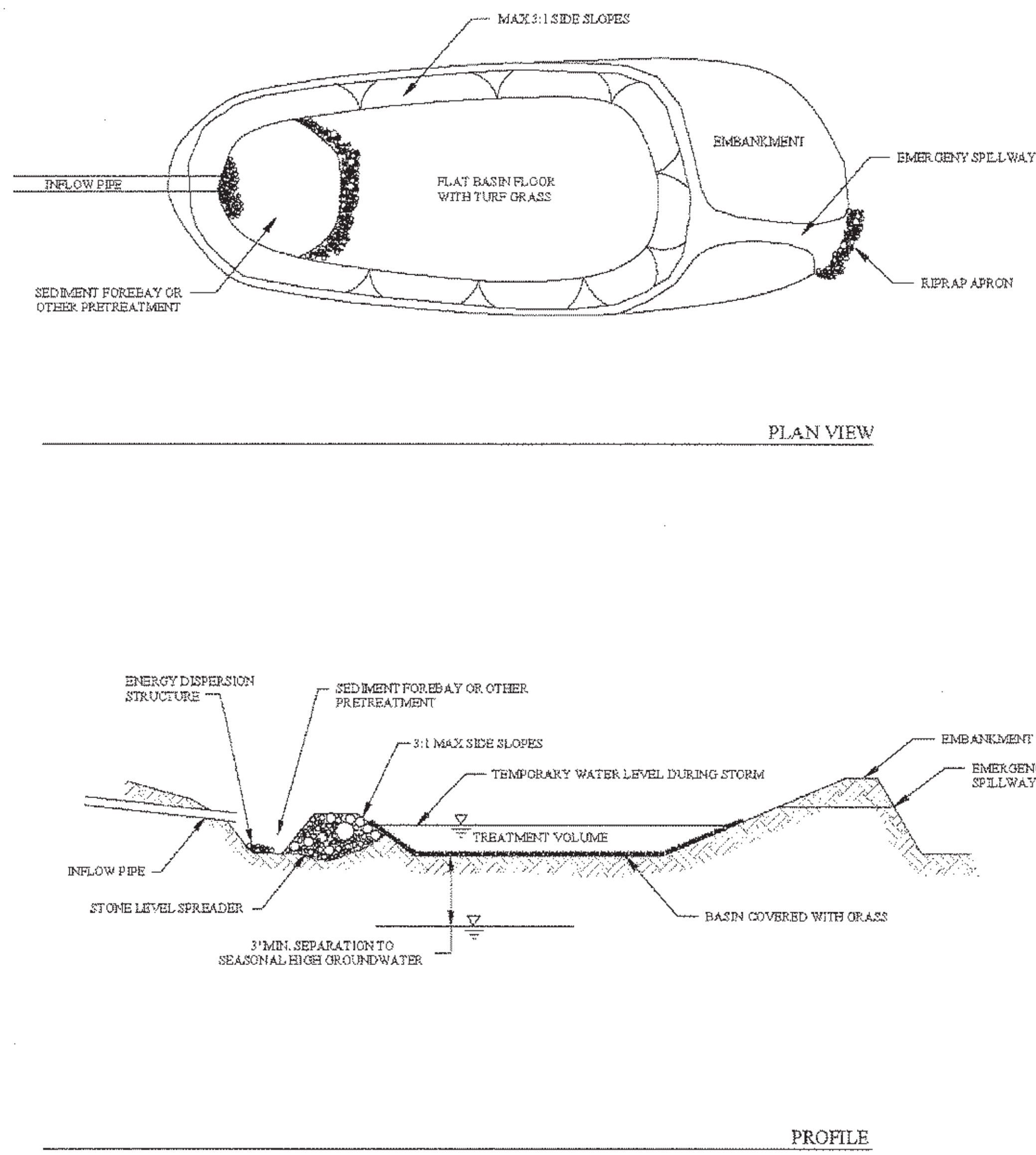


FIGURE 6-4. TYPICAL INFILTRATION BASIN

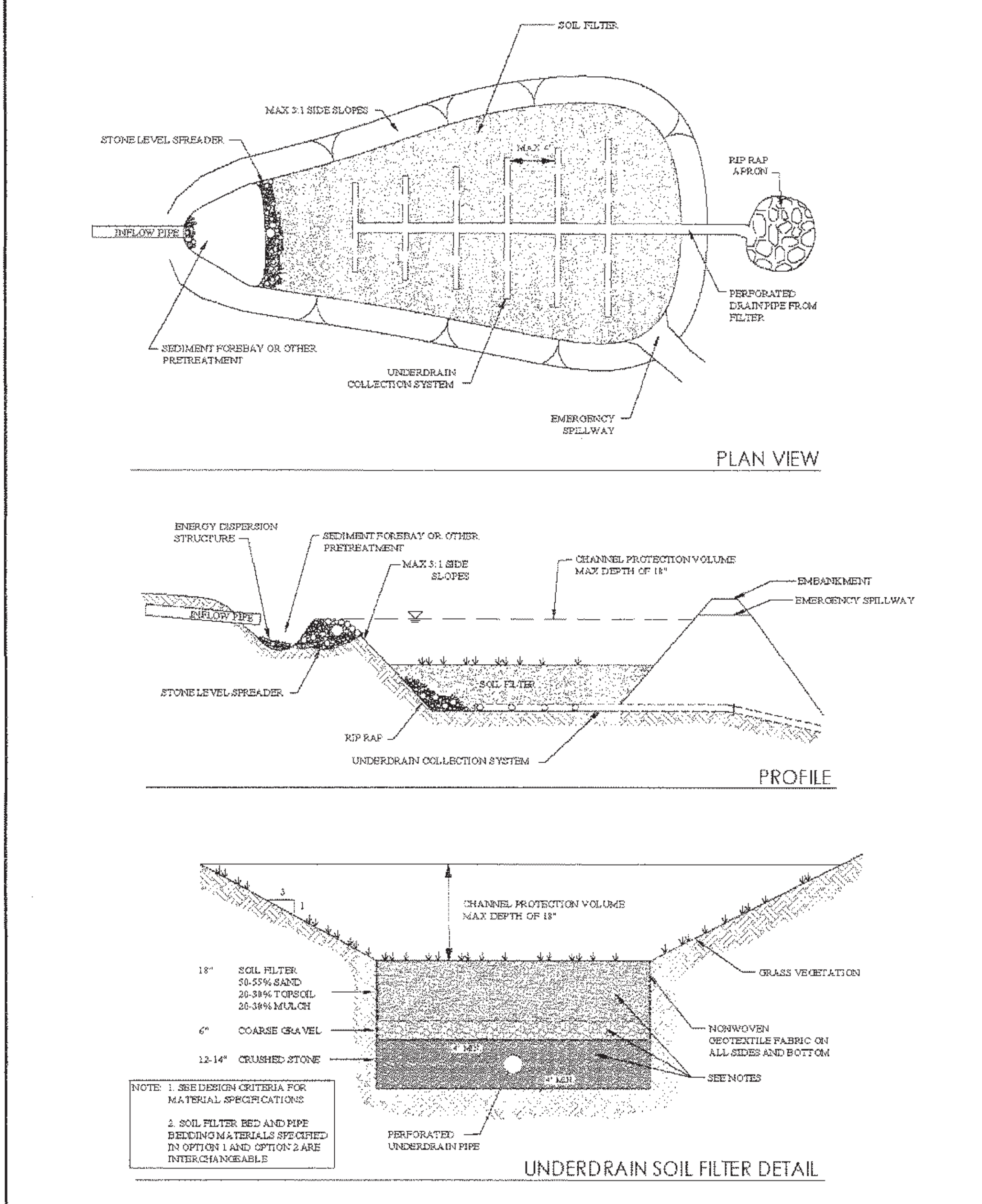


FIGURE 7-1. VEGETATED UNDERDRAIN SOIL FILTER FIELD (OPTION 1)

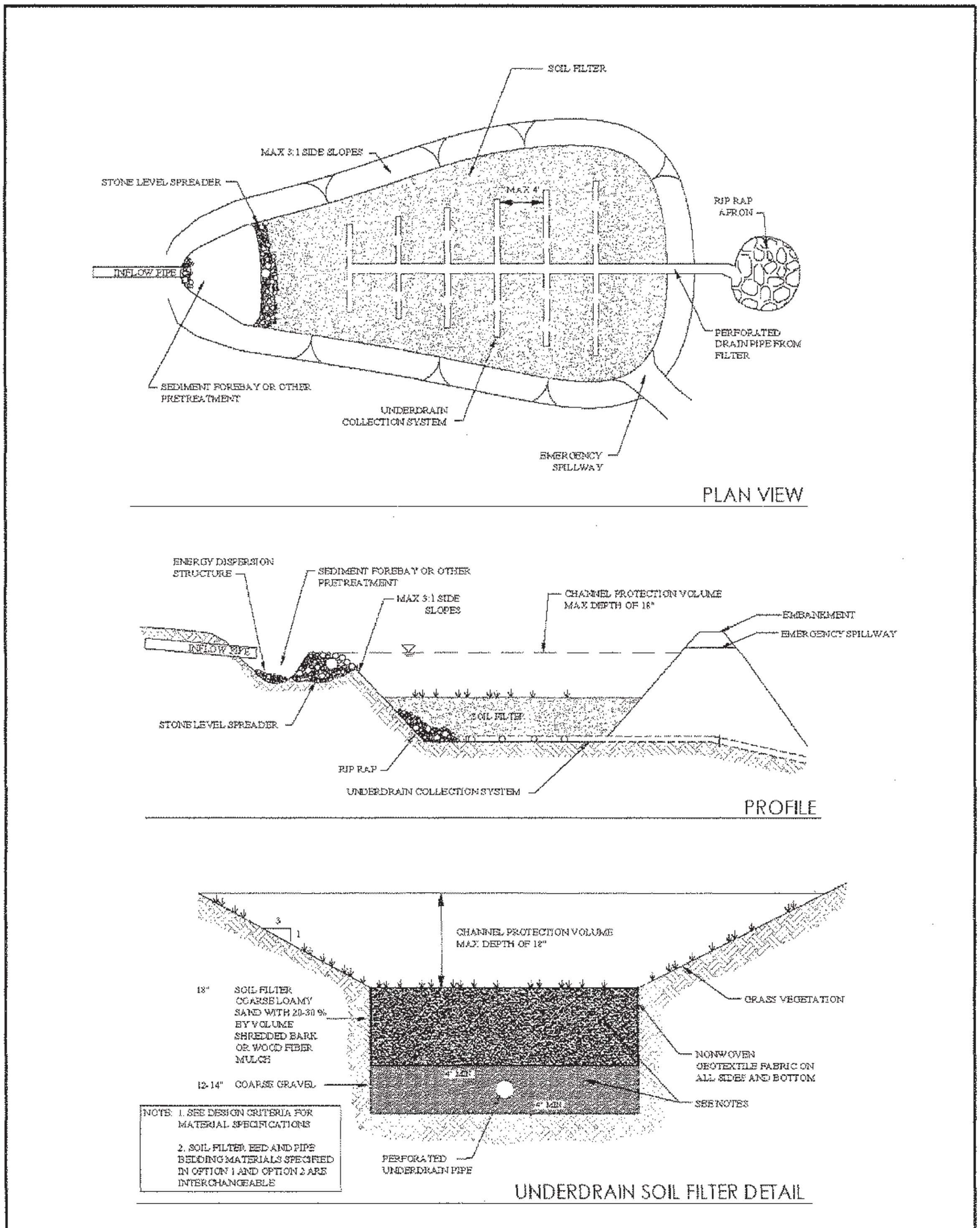


FIGURE 7-2. VEGETATED UNDERDRAIN SOIL FILTER FIELD (OPTION 2)

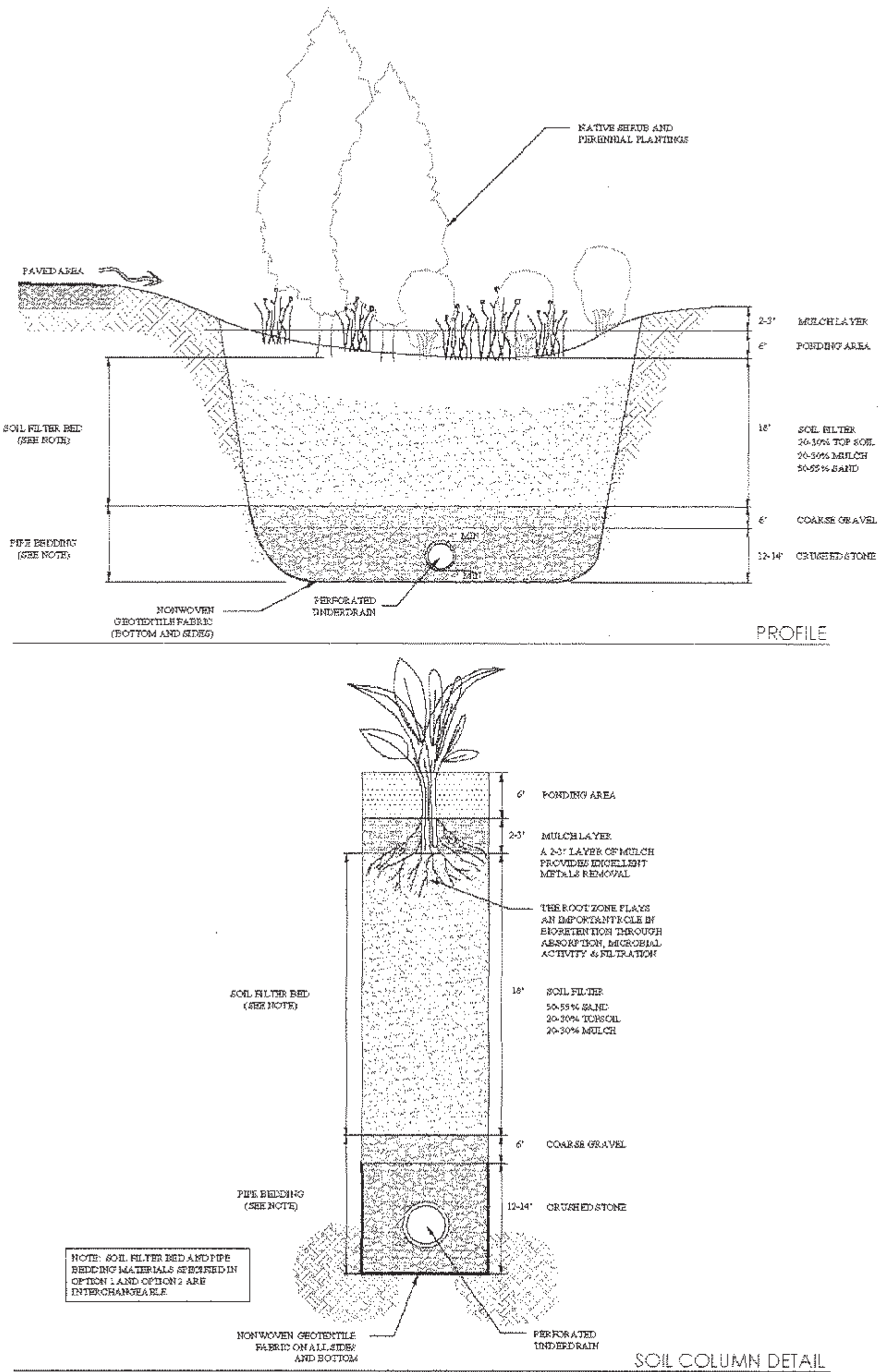


FIGURE 7-3. TYPICAL BIORETENTION CELL (OPTION 1)

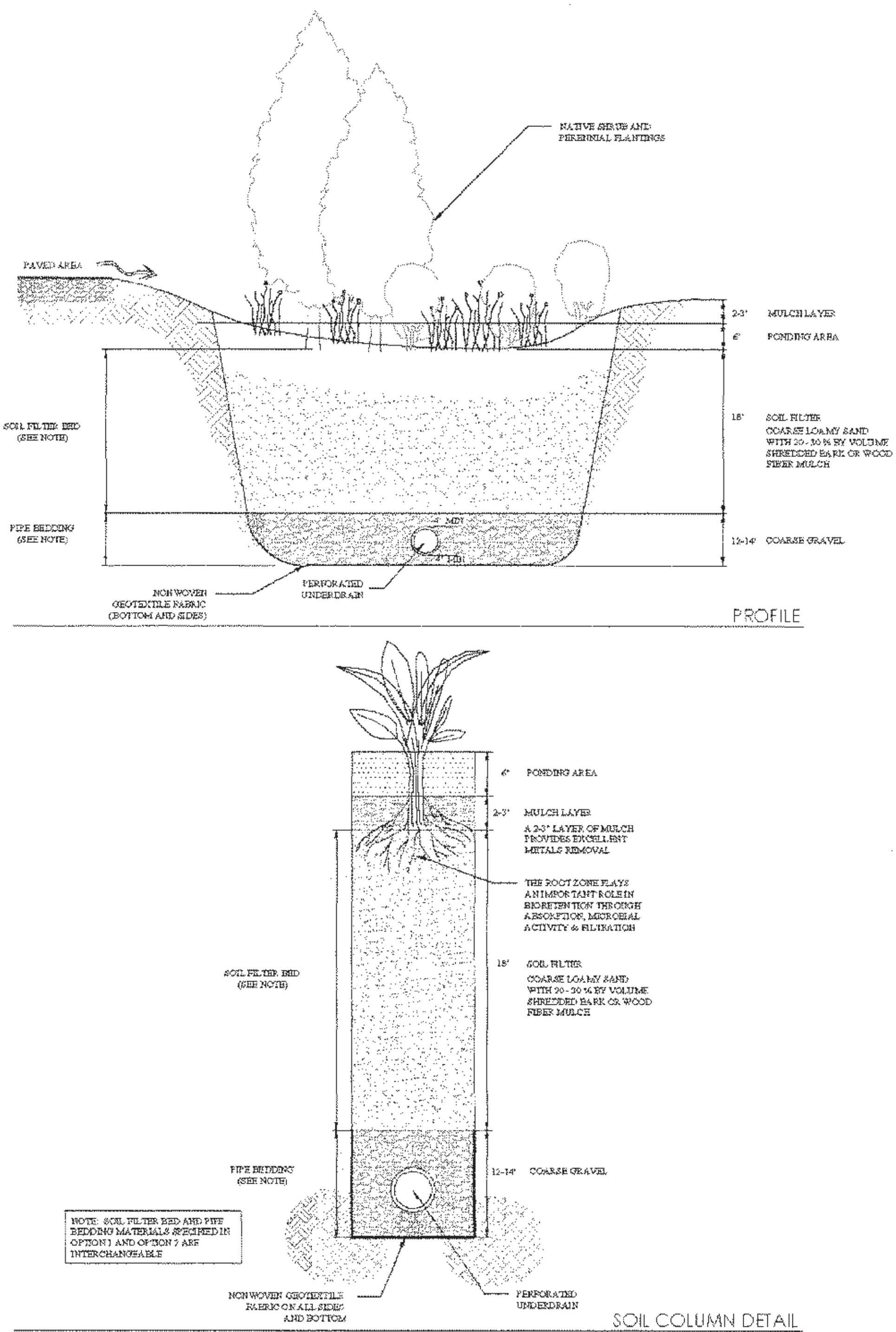


FIGURE 7-4. TYPICAL BIORETENTION CELL (OPTION 2)

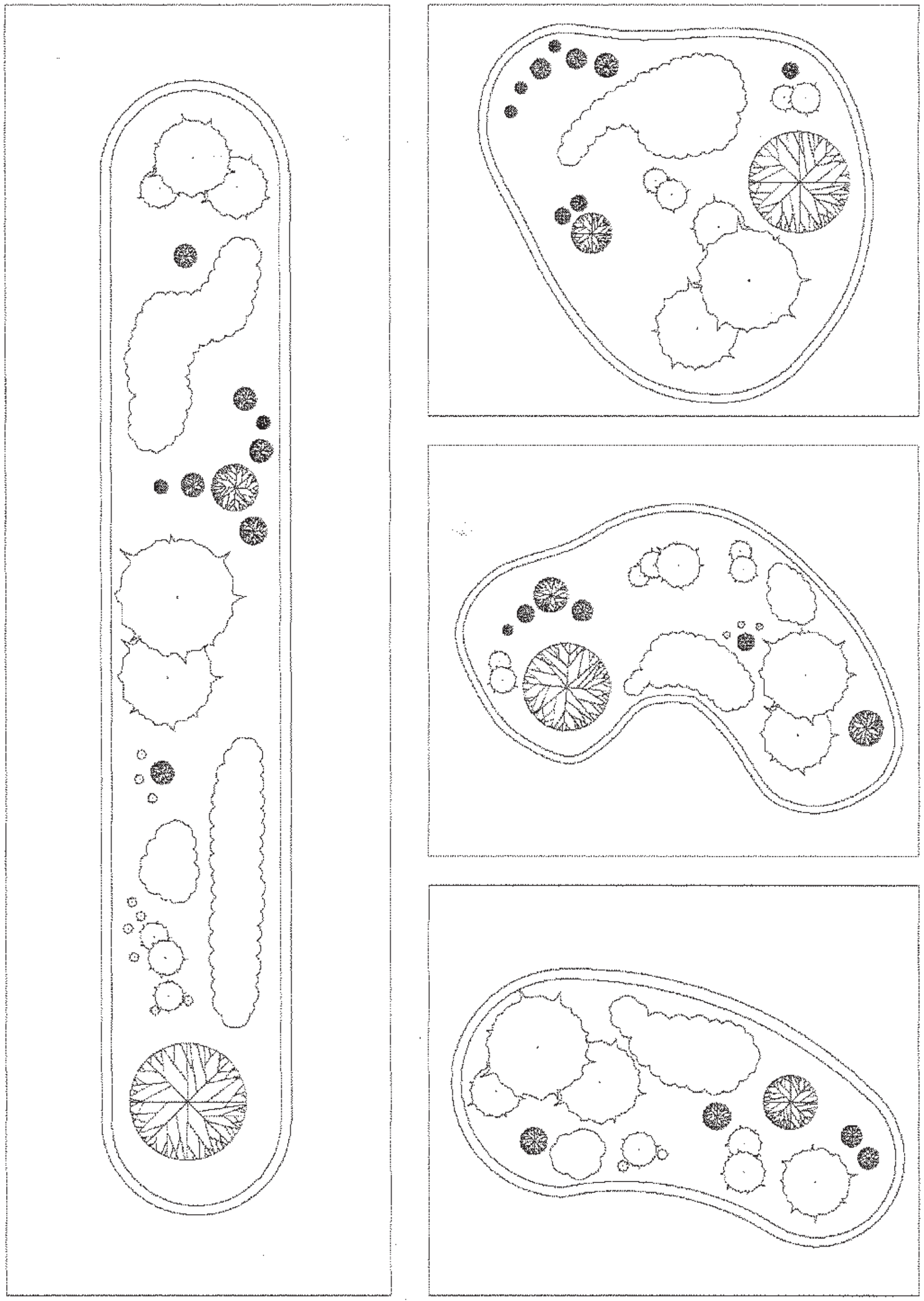


FIGURE 7-5. ALTERNATIVE SOIL FILTER LAYOUTS

NOTE: ALTERNATIVE LAYOUTS CAN BE USED FOR BOTH VEGETATED UNDERDRAIN SOIL FILTER FIELDS AND BIORETENTION CELLS

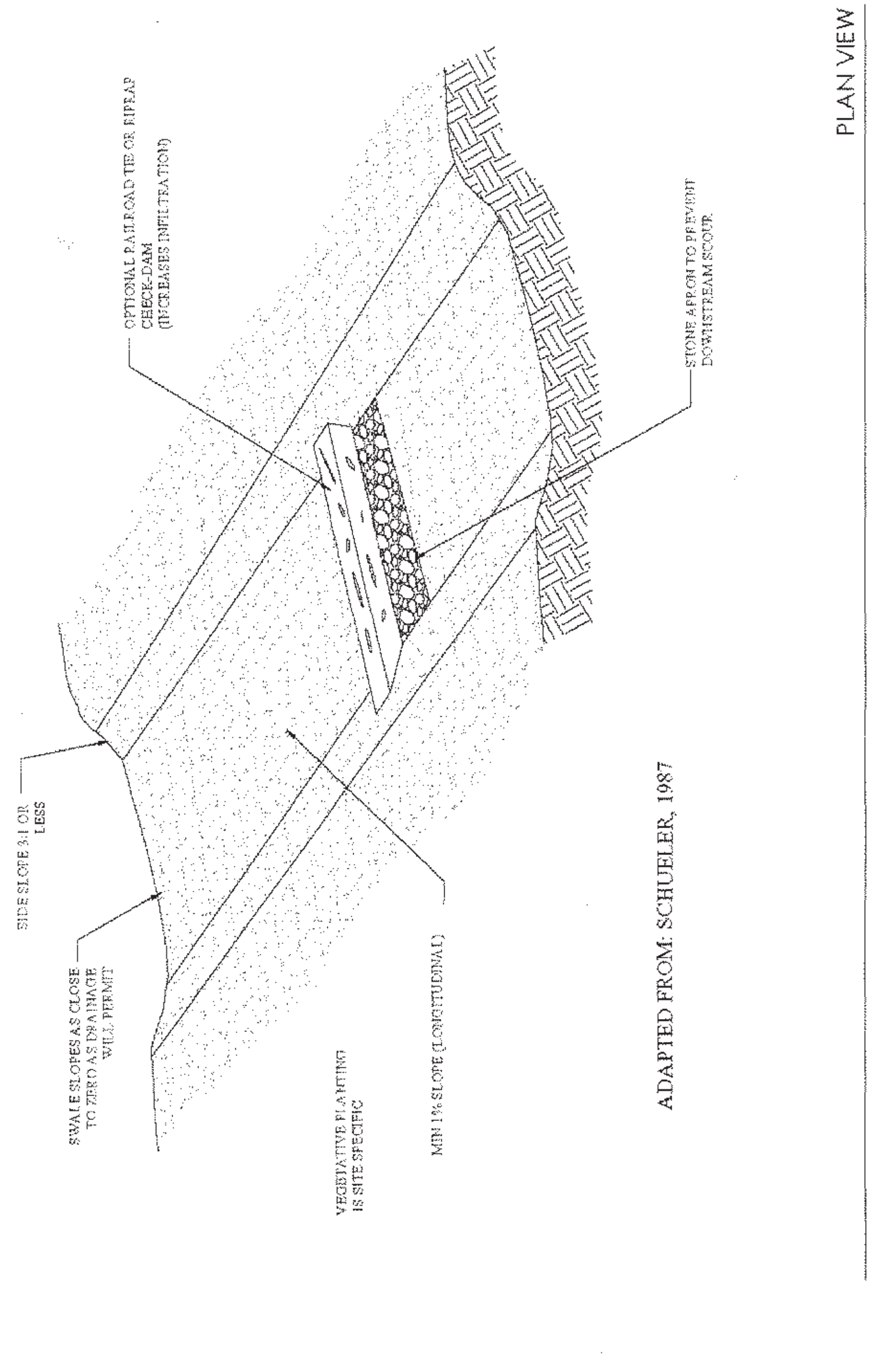


FIGURE 8-1. TYPICAL SWALE WITH CHECKDAMS

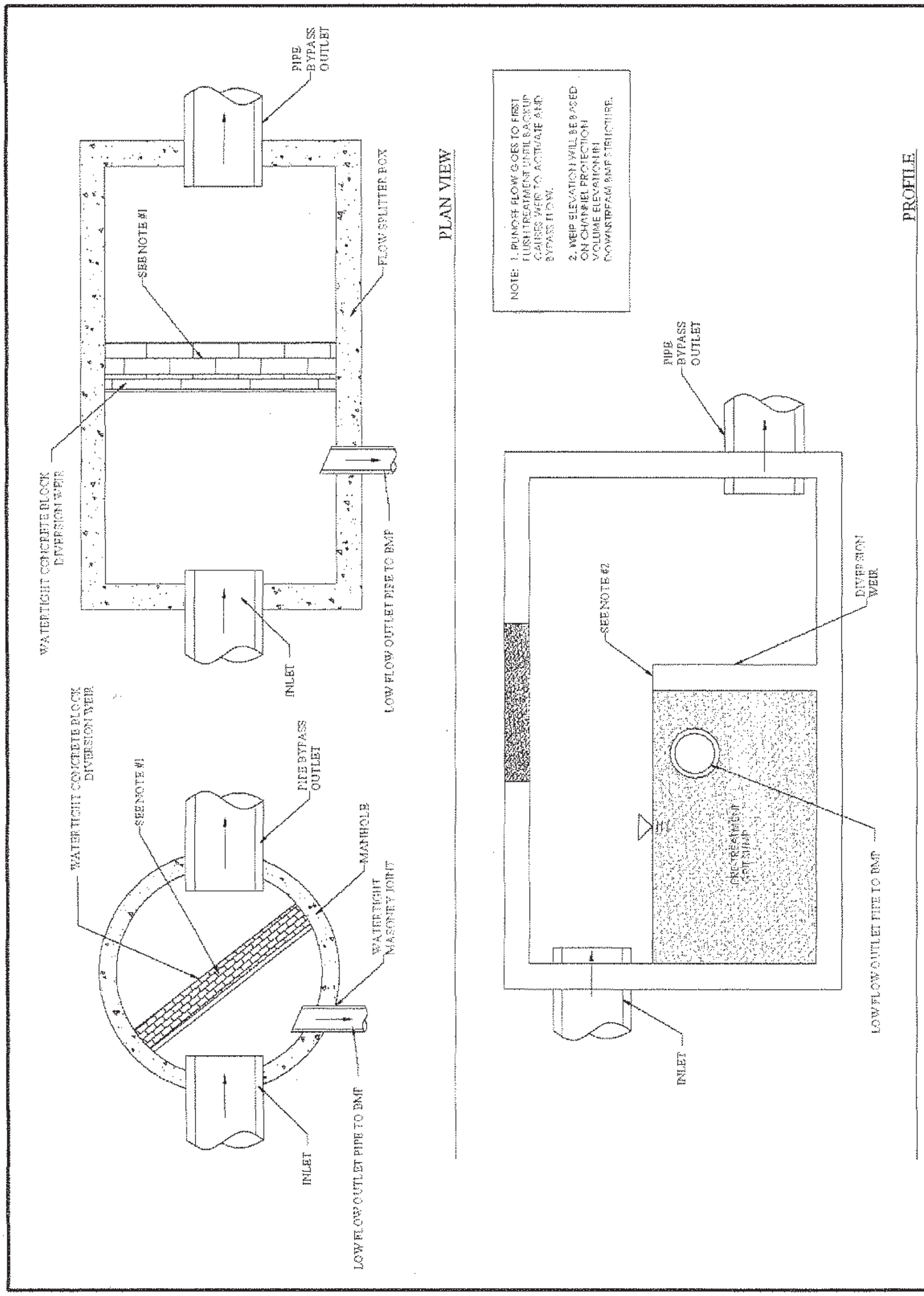


FIGURE 8-2. FLOW SPLITTER

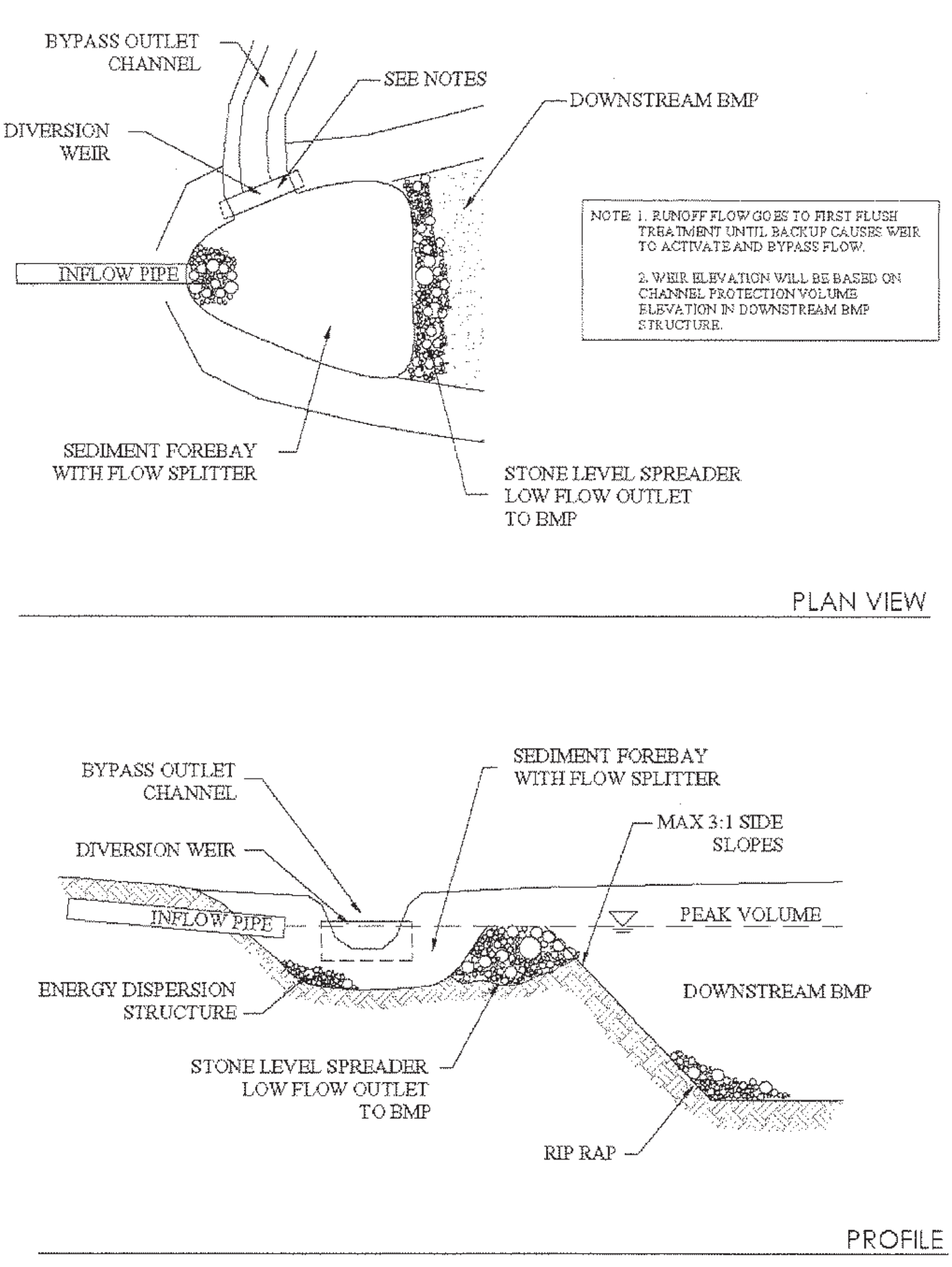


FIGURE 8-3. TYPICAL SURFACE FLOW SPLITTER IN FOREBAY

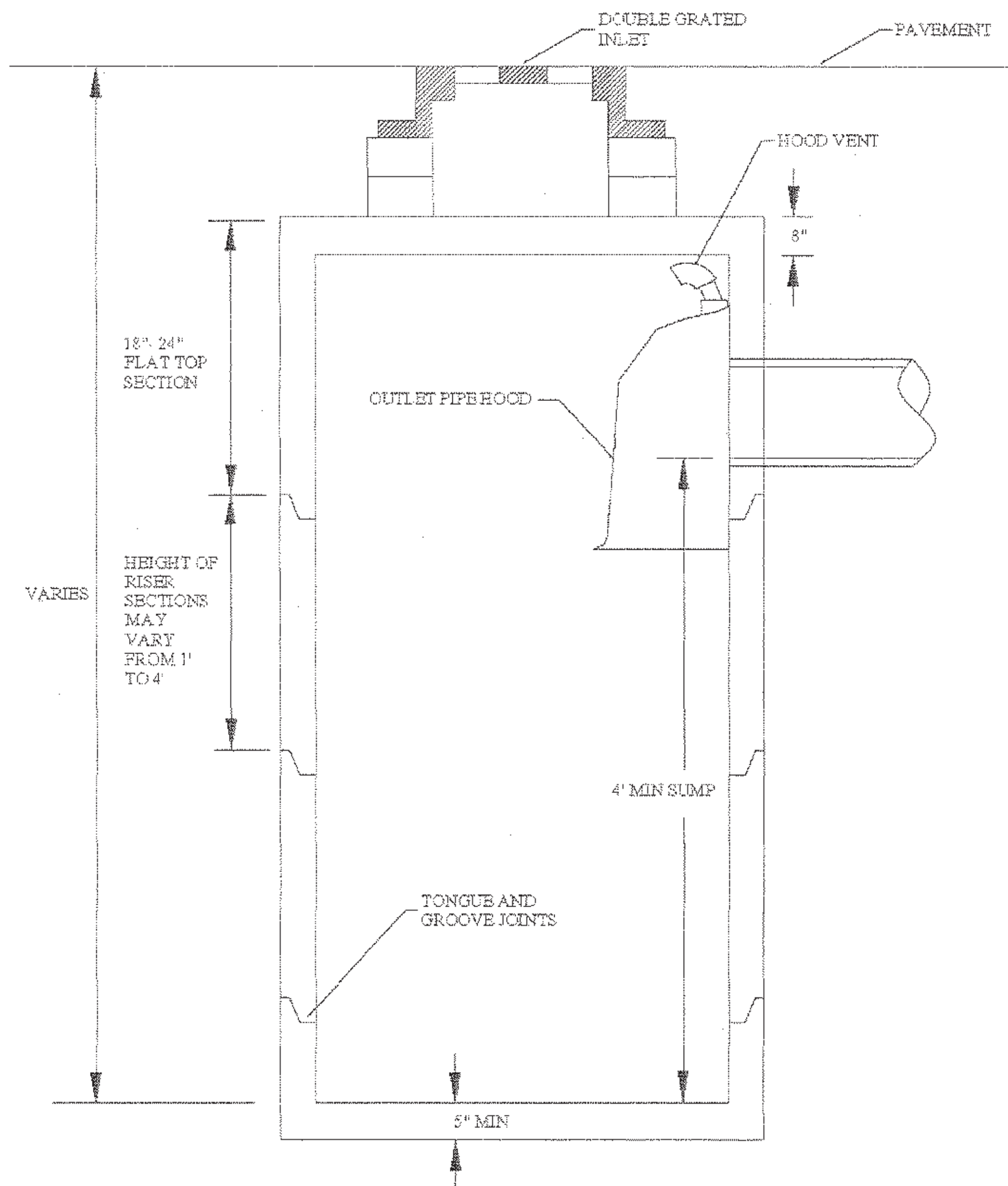


FIGURE 9-1. WATER QUALITY INLET

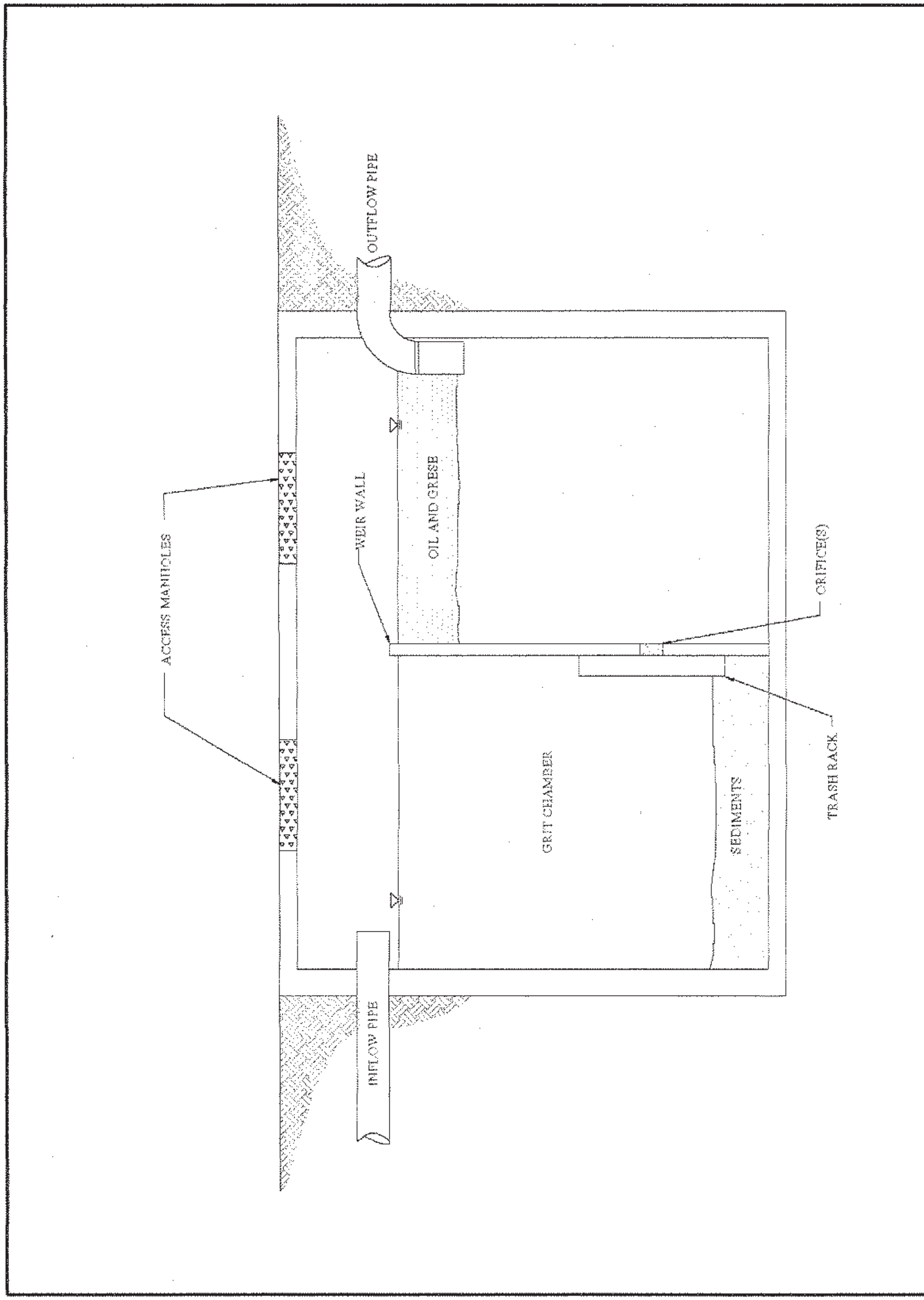


FIGURE 9-2. TYPICAL OIL/GRIT SEPARATOR

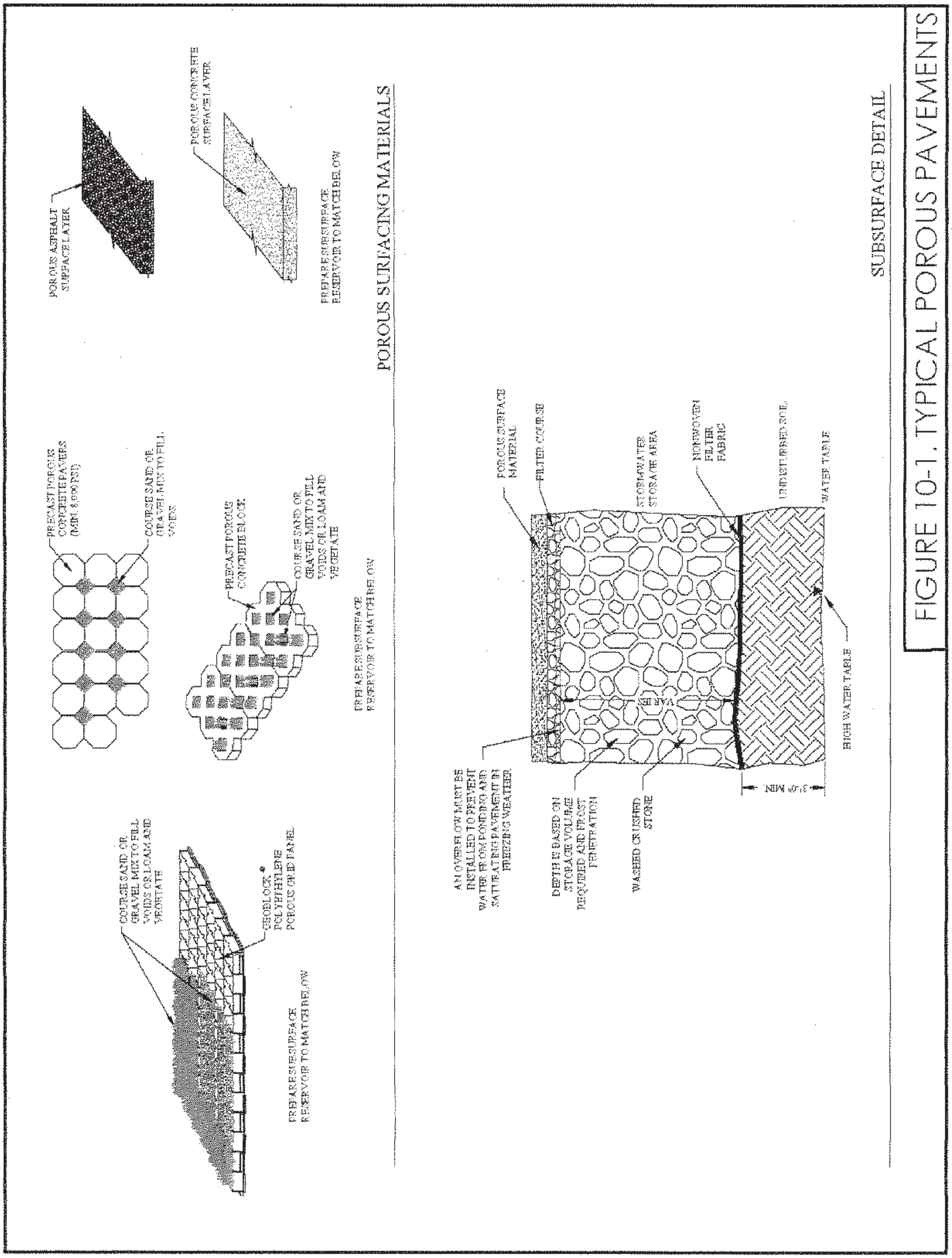


FIGURE 10-1. TYPICAL POROUS PAVEMENTS

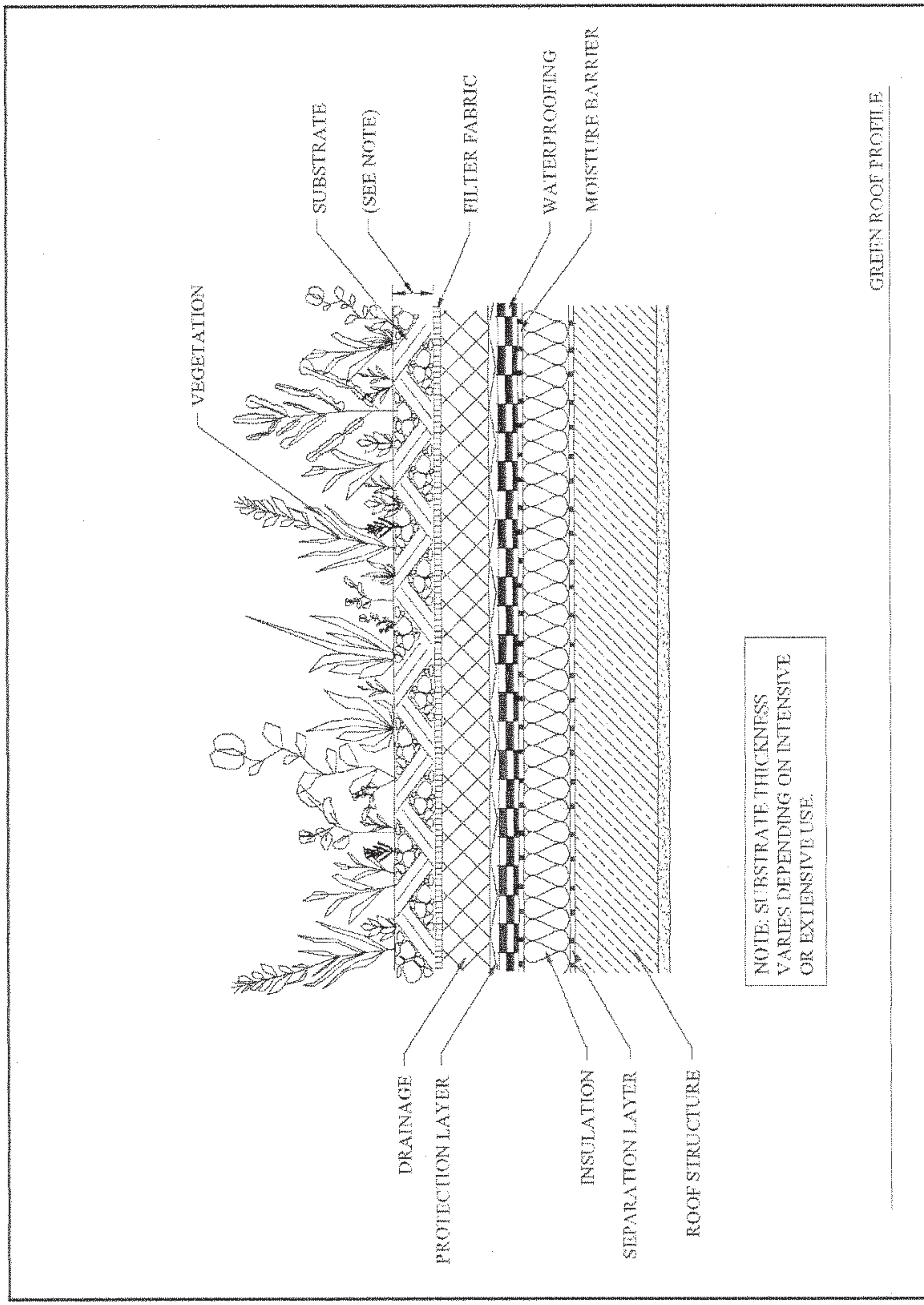


FIGURE 10-2. TYPICAL GREEN ROOF