Development of a BMP Demonstration Project within Wonderland Drainage Basin for Control of Stormwater Runoff to Rapid Creek
Rapid City, SD

Prepared for :
SD Department of Environment and Natural Resources
and
City of Rapid City

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SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM – IMPLEMENTATION PROJECT FINAL REPORT

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Rapid City, South Dakota

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Date:

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This project was conducted in cooperation with the State of South Dakota, City of Rapid City, and United States Environmental Protection Agency, Region 8

Grant # C9998185-99

Executive Summary

PROJECT TITLE: Development of a BMP Demonstration Project within Wonderland Drainage Basin for Control of Stormwater Runoff to Rapid Creek.

PROJECT START DATE: 05/01/99 PROJECT COMPLETION DATE: 12/31/04

FUNDING: TOTAL BUDGET: $ 94,942.00

TOTAL EPA GRANT:	$59,465	
TOTAL EXPENDITURES OF EPA FUNDS:	$56,210	
TOTAL EXPENDITURES OF NATURAL RESOURCE FEE FUNDS:	$ 2,500	
TOTAL SECTION 319 MATCH ACCRUED	ORIGINAL BUDGET	ACTUAL EXPENDITURE
CITY OF RAPID CITY:	$33,511	$31,199
SDSM&T	$ 4,466	$ 7,027
TOTAL	$37,977	$38,226
BUDGET REVISIONS:	$ 2,500	
TOTAL EXPENDITURES:	$96,936	

FUNDING SUMMARY:

The above budget represents funding sources and expenditures for the Development of a BMP Demonstration Project within Wonderland Drainage Basin for Control of Stormwater Runoff to Rapid Creek (grant # C9998185-99). The EPA section 319 grant provided 60 percent of the funding for the project. The City of Rapid City and South Dakota School of Mines and Technology (SDSM&T) contributed the local match for the project. The budget revision was additional section 319 funding provided by SD DENR to attend a TMDL water quality modeling workshop. This grant funded an evaluation of methods for control of stormwater quality management and the design and construction of an erosion control structure in Wonderland basin. This report summarizes the evaluation of stormwater quality control measures and presents the design characteristics of the erosion control structure.

SUMMARY OF ACCOMPLISHMENTS:

The goal of the project was to integrate best management practice (BMP) components for storm water runoff into the development of the master drainage design plan for Wonderland Basin. This has been done in conjunction with the City of Rapid City's (City) completion of the master drainage design plan. The project resulted in a hydrologic analysis of Wonderland basin identifying the effects of increased impervious area and the potential benefits of implementing BMP's. The three general BMP categories that best integrate into the Wonderland Basin Master Drainage Plan are low impact development (LID), extended detention basins and stable drainage channel design.

One of the primary concerns within the Wonderland Basin is increased impervious area generating more frequent and higher runoff peak flows. Hydrologic modeling of the basin has shown that implementation of LID BMPs could reduce the peak flow for frequent runoff events (2-year through 10-year) by up to 36 percent. The highest priority BMP selected for implementation was channel stabilization of a major head cut in the main channel (93 % of the basin contributes runoff to this point). The construction of this BMP was completed.

A report entitled "Low Impact Development, A Potential Stormwater Management Solution for Rapid City, South Dakota" that provides information on low impact development and BMPs was prepared. This report has been distributed to selected members of the community. Several landowners within Wonderland Basin were contacted regarding implementation of LID BMPs. Although, there seemed to be favorable consideration of the concept of LID, it is likely that implementation will require the City to recognize and require consideration of LID BMPs within the City's Drainage Criteria Manual. An open information presentation was made to the Rapid City Common Council on August 14, 2000. This meeting was attended by developers, six council members, City staff and other members of the public.

It is recommended that the City's Drainage Criteria Manual be revised or updated to include stromwater quality management. Effective stormwater management in Rapid City must include a significant public education component.

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I. Introduction

South Dakota's Nonpoint Source Management Program Plan Update (SD Department of Environment & Natural Resources, 1991) identifies waters to undergo intense efforts for control of nonpoint pollution sources within the watershed. South Dakota's rivers were ranked based on information in the Nonpoint Source Assessment Report, the 305(b) Water Quality Report and best professional judgment of SD Department of Environment & Natural Resources (SD DENR). This ranking recognized seven criteria: 1) beneficial use, 2) public health risk, 3) public recreational use, 4) off-site effect, 5) special consideration, 6) hydrologic unit plan priority, and 7) groundwater connection. The highest possible impairment score is 100 points. Rapid Creek below Rapid City to the mouth of the Cheyenne River received a score of 62. Rapid Creek from Pactola Reservoir to below Rapid City with had score of 61. Additionally, Rapid Creek below Rapid City to the mouth at the Cheyenne River was identified as impaired Total Maximum Daily Load Water for the parameters fecal coliform and total suspended solids.

The segment of Rapid Creek in the project area has the following beneficial uses (SD DENR 1994); domestic water supply waters, coldwater permanent fish life propagation waters, immersion recreation waters, limited contact recreation waters, wildlife propagation and stock watering, and irrigation. Of these beneficial uses, coldwater permanent fish life propagation requires meeting the most stringent water quality standards. Three of the more stringent criteria require that total suspended solids (TSS) must be less than 30 mg/l (30 day average) or 53 mg/L daily maximum, dissolved oxygen must be greater than 6.0 mg/l, and dissolved oxygen in spawning reaches must be greater than 7.0 mg/l. With regard to domestic water supply beneficial use criteria, the bacteriological criteria for coliform are an important consideration. Harms et al. (1983) conducted wet weather sampling on Rapid Creek from 1980-1982 as part of the National Urban Runoff Program. The study evaluated the impact of stormwater runoff on the beneficial uses for Rapid Creek. Table 1 shows a comparison of the most stringent criteria with observed in-stream values.

Table 1.1 Comparison of water quality criteria and observed values.

Parameter	Most Stringent Criterion	Observed Values In Stream		Comment
		Minimum	Maximum	
Ammonia NH_3-N, mg/l	0.3	< 0.03	0.67	violation
Suspended Solids, mg/l	53 (daily max)	2	2300	violation
Fecal coliform, #/100ml	400 (daily max)	35	68,000	violation

Based on observations, the following conclusions were drawn from the study;

- water quality standards were violated during periods of runoff
- water quality during low flows is being degraded but still meets the stream's water quality criterion, and
- water quality is being degraded by stormwater runoff as the stream flows through Rapid City

Kenner and Craft (1997) completed a study which included direct sampling of three stormwater runoff events from the Arrowhead drainage basin within Rapid City. Arrowhead drainage basin is one of four drainage basins located in west Rapid City; the others being Wonderland, South Canyon, and Red Dale. Table 2 gives the range of event mean concentrations (EMC) for parameters of concern. These results support the potential for water quality standards violations occurring during wet weather runoff.

Table 2.1 Arrowhead Drainage Basin stormwater quality.

Parameter	EMC Range (mg/l)
Ammonia as N	< 0.05 to 0.1
Total suspended solids	47 – 89
Total Coliform (# per 100ml)	39,000 - 280,000
Fecal Coliform (# per 100 ml)	610 – 3,200

1.1 Rapid Creek Characteristics

Rapid Creek, drains an area of about 700 mi^2. The creek is a perennial stream that originates in the limestone plateau within the Black Hills and flows eastward through Rapid City. The upstream reach of Rapid Creek has an average gradient of about 48 feet per mile, and is comparatively narrow and fast running. The stream bed consists of sand, gravel, and cobbles derived from surrounding surface exposures of crystalline rock, sandstone, and limestone. In Rapid City, Rapid Creek turns to the southeast and flows 70 miles to its confluence with the Cheyenne River near Creston, South Dakota. Within this reach, the gradient is about 13 feet per mile, and stream velocities are considerably less than upstream. Upstream and through Rapid City, the stream has a fairly stable channel that is armored during low flows. At high flows, some bank erosion occurs that is controlled by either rock outcrops or stream bank vegetation.

Flow characteristics of Rapid Creek are controlled through the management of two reservoirs: Deerfield and Pactola. Deerfield is located on Castle Creek about 53 miles upstream of Rapid City and has a storage capacity of 15,504 acre-feet. Pactola is located on Rapid Creek about 21 miles upstream of Rapid City and has an active storage of 54,955 acre-feet. The long-term average annual discharge in Rapid Creek near Rapid City is approximately 34 ft^3/sec.

This water resource provides water for domestic, irrigation, fisheries and recreational uses. Rapid City obtains most of its water supply from three shallow, horizontal, infiltration galleries located in the Rapid Creek alluvial aquifer. These galleries have a combined production capacity of approximately 11 million gallons per day. Irrigation withdrawals from Rapid Creek are extremely variable but are normally about 30 ft^3/sec. The SD Depatment of Game Fish and Parks (GFP) has managed Rapid Creek through Rapid City as a trout fishery since the middle 1970s. The stream segment supports 1,800 to 2,100 trout per mile.

1.2 Watershed Management

The Rapid Creek Watershed can be divided into three reaches, 1) above Pactola Dam, 2) from Pactola Dam to Rapid City (upstream of Canyon Lake), and 3) below Canyon Lake through Rapid City. A significant portion of the watershed area above Pactola is managed by the Black Hills National Forest. The Forest Service has an active watershed management program that is identifying impaired areas and implementing appropriate control measures. The reach from Pactola Dam to Canyon Lake has a larger portion of area that is private. One of the primary concerns in this stream reach is control of nutrient and sediment loading to Canyon Lake. A 319 project to reduce the nutrient loading to Canyon Lake was proposed but not funded. The City of Rapid city has completed work on Canyon Lake which included sediment removal and improvement of in-lake hydraulics. Additionally, a joint City/county committee evaluated options for control of septic tank systems, especially along the riverine corridor from Canyon Lake to Pactola. Below Canyon Lake, master drainage plans for watershed areas that are impacted by urbanization and have significant potential to impact the water quality of Rapid Creek have only considered control of stormwater quantity. Thus, the reach below Canyon Lake has had limited effort toward implementation of management practices that control impacts on water quality.

1.3 Urban Watershed Characteristics

The expanding urban Rapid City area has a current population of approximately 65,000 people. The City has grown by almost 20,000 people since the 1980 census. The climate in the Rapid City area is typical of temperate, semiarid continental climates.

Temperature fluctuations range from summer maximums above 90 ^oF to winter minimums of -30 ^oF, with an annual average temperature of 67 ^oF. The distribution of precipitation during the year is uneven with a distinct “rainy season” during the late spring and early summer months. More than 60 percent of the annual precipitation falls from April through July.

The affected drainage area immediately below Canyon Lake covers 42,680 acres and contains 26 sub-watersheds. The sub-watersheds range in size from 126 to 6,245 acres, with an average size of 1708 acres. In general, slopes range from greater than 40 percent in the upstream reaches to less than 2 percent in the downstream reaches.

General land use is 40 percent agricultural, 30 percent residential, 25 percent commercial/industrial and 5 percent park/forest. Soil characteristics range from rock outcrop and shallow rock covered with varying depths of loam transitioning to a clayey loam then to shale toward the downstream parts of the watersheds. Kenner and Craft (1997) developed detail mapping of these watershed and watershed characterisitcs.

The most critical reach of Rapid Creek is from Canyon Lake to Omaha Street because this reach is the primary trout spawning reach and is immediately upstream of the Rapid City water treatment plant intake. The sub-watersheds affecting this reach of Rapid Creek are South Canyon (SC), Red Dale (RD), Wonderland (WD), and Arrowhead (AH). Of these Wonderland and Arrowhead are experiencing significant development.

1.4 Wonderland Drainage Basin Characteristics

Wonderland drainage basin is located in southwest Rapid City. This drainage basin is the first sub-basin to empty into Rapid Creek below Canyon Lake. The drainage from the basin enters Rapid Creek 500 yards below Canyon Lake Dam within Meadowbrook Golf Course. The sub-basin varies in residential development throughout its two-mile channel length. The bottom third of the sub-basin is highly developed with a moderately sloping channel. The middle third of the sub-basin is highly/moderately developed with a moderate channel slope. The upper third of Wonderland drainage basin is relatively undeveloped with a high channel slope occurring through hilly terrain. A new elementary and middle school has been built in the upper reaches of the basin and the area will likely see continued development in the future.

1.5 Watershed Water Quality Problem

Limited water quality data are available for the project area. Water quality results from previous projects were presented in section 2.1. Based on previous studies (Harms et al., 1982 and Kenner and Craft, 1997), the primary water quality impairment is due to sediment and those parameters associated with sediment. Additionally, there is a concern regarding high concentrations of bacteria within the Arrowhead watershed. A secondary concern is increasing nutrient loading with increasing development. Increasing nutrient load from stormwater, occurring on a continuous basis, results in a steady decline in water quality and spawning habitat. The GFP conducts an annual fish population survey of Rapid Creek. Results over the past five years have shown significant declines in catchable (8”) size fish during 1994 and 1995, and a slight increase during 1996. There is not enough information to identify any single cause for the decline. To establish better baseline conditions, a study of macroinvertebrates and characterize stream bed substrate has been initiated. The limited amount of data available does not lend itself to calculation of pollutant loadings from stormwater runoff.

II. Project Goals and Objectives

The goal of this project was to reduce pollutant loadings to Rapid Creek from urban stormwater runoff produced within the Wonderland drainage basin. Reduction of sediments and associated pollutants will provide protection of existing beneficial uses. Presently, drainage basin design plans developed for Rapid City watersheds are designed to ensure adequate conveyance of runoff. One project objective was to integrate control of stormwater quality into the existing drainage design plans. Sediment control structures and vegetation-lined channels are two primary features commonly used to convey stormwater runoff. In addition to structural controls, LID BMPs are recommended. LID BMPs are cutting-edge, tested ideas which place the burden of stormwater management onto the developer. By providing the developer and the homeowner cost effective, simple techniques, stormwater is significantly reduced at an individual property in quantity and in pollution downstream.

Evaluation of the Wonderland Basin and land use shows that a single control structure at the outlet of the watershed would not be feasible. The proposed approach for the project was to locate three structures along the basin, each controlling the “first flush” from approximately 1/3 of the basin. Flows exceeding the first flush will bypass the structures. The proposed structures were to be linked with vegetated channels to prevent channel erosion and promote sediment removal during frequent events. The first of these structures is currently being designed by the City and is located near the outlet. This project will integrate the capacity of the downstream structure for locating the next upstream structure which is proposed for this project. The objectives and tasks completed to meet the project goals are presented in the following section.

III. Hydrologic Analysis and Stormwater BMPs for Wonderland Basin

The evaluation completed to identify BMP’s for Wonderland Basin included two primary components 1) a basin walk through, and 2) hydrologic analysis. Each of these components is discussed below.

3.1 Wonderland Basin Walk-Through

The walk-through of the basin was conducted March 2, 2000. The purpose of the walk-through was to identify critical areas within the watershed to be considered for implementation of BMPs. Evaluation of the walk through identified three critical areas. Additionally, open areas that represent relatively undisturbed conditions within the basin were identified. These areas are described in Table 3.1. Photographs of these areas are presented in Figures 3.1 – 3.6.

The areas of concern identified are related to drainage channel encroachment and increased runoff due to development. These conditions combine to create various erosion problems. Based on the basin walk-through and priority ranking of critical areas, the initial focus of BMP implementation was directed toward the head-cut just upstream from Park Drive.

Table 3.1 Description of drainage conditions in Wonderland Basin.

Location	Area Description	Hydrologic Condition	Priority	Photo
Approximately 100 feet upstream of Park Drive	Severe head-cut measuring 8 feet deep by 25 feet across	Critical	1	Figure 3.1
Duplex Development along west side of Park Drive, east side of Wonderland drainage. Several locations upstream from Park Drive.	Drainage channel encroachment, steep banks with potential erosion, various stages of development	High	3	Figures 2.2 & 3.3
Side drainage from east storm drain	Outlet of small storm drain at top off steep bank erosion significant at bottom near main drainage channel	High	2	Figures 3.4 & 3.5
Natural drainage channel conditions various locations along the drainage	Natural drainage conditions show significant grass and vegetation and stable channel	None	NA	Figure 3.6

Figure 3.1 Photograph looking upstream at head cut in Wonderland Basin main drainage channel.

Figure 3.2 Recent encroachment into drainage channel cutting off main drainage channel.

Figure 3.3 Bank erosion of fill material placed for earlier development.

Figure 3.4 Intersection of storm drainage with main drainage. Storm sewer outlet directed over steep bank fill material.

Figure 3.5 Outlet of storm drain with inadequate erosion control. Outflow directed to very steep bank.

Figure 3.6 Relatively natural drainage channel conditions.

3.2 Hydrologic Analysis

The hydrologic analysis was conducted by SDSM&T and a consultant hired by Rapid City. Although the objectives for the modeling were different, the two groups collaborated on model development. The objectives of the City hydrologic modeling were to develop a Master Drainage Plan for Wonderland Basin. The master drainage plan focused primarily on hydrologic modeling of extreme events (100 year flooding) for drainage purposes. The master drainage plan does not take into consideration stormwater quality considerations. The final Master Drainage Plan for Wonderland Basin is available from the City of Rapid City (Ferber Engineering, 2001). The existing culvert under Park Drive and the box culvert under Western Avenue control capacity of the Wonderland drainage basin. Based on the analysis of future developed conditions, the master drainage plan recommended five detention structures in the upstream basin. The detention structures are preliminarily sized to control 100 year flows.

Hydrologic modeling conducted by SDSM&T was done to evaluate the impact of increased impervious area and provide information on the benefit of implementing LID BMPs. A final report on the model development and results is provided in Appendix A (Coon, 2000). The results are summarized here. The hydrologic model was developed to simulate pre-development conditions (undeveloped), existing development conditions (and average of 25 to 30 percent impervious) and future developed conditions. Models were run to simulate several rainstorm frequencies. The design rainstorms were developed following the methods described in the Rapid City Drainage Criteria Manual (City of Rapid City, 1989). Table 3.2 presents the results of the hydrologic modeling for each rainstorm and development condition simulated.

Table 3.2 Modeling results for Wonderland Basin under different development conditions and for several rainstorm events.

Rain Storm Frequency	Pre-Developed	Existing Conditions			Future Conditions		
	Peak Flow (cfs)	Peak Flow (cfs)	Increase (cfs)	% Increase	Peak Flow (cfs)	Increase (cfs)	% Increase
2-year	9	70	61	678	97	27	39
5-year	80	168	88	110	213	45	27
10-year	128	219	91	71	267	48	22
25-year	286	368	82	29	424	56	15
50-year	464	541	77	17	607	66	12
100-year	677	743	66	10	821	78	11

The peak flow at the outlet of the basin is given for each rainstorm and development condition. For existing conditions, the increase represents the increase in peak flow from pre-developed conditions for a given rainstorm. Likewise, the increase for future conditions represents the increase in peak flow above existing conditions. The percent increase in peak flow is also given. The results clearly demonstrate that the most significant impact on peak flows occurs at the lower return periods, 2-year through 10-year. From pre-developed conditions to existing conditions the 2-year peak flow increases 678 percent and the 10-year increases 71 percent. However, the 100-year increases only 10 percent from pre-developed to existing conditions. This is because during a 100 year rain storm, most of the ground becomes saturated and contributes to runoff, and increases in impervious area do not have as significant of an effect. However, during a low return period runoff is only generated from impervious area. Therefore, there is a larger effect on the peak flow.

If it is recognized that channel and drainage morphology is formed primarily by the annual average peak flow (2.3 year return period), it becomes apparent that the significant increase in the lower return period peak flows causes instability in the drainage and subsequent erosion problems. Further analysis of the effects and channel enlargement are presented in Appendix A. These results agree with the literature (ASCE, 1998) in that stormwater quality issues are created by the lower return period events (2-year through 10-year). Thus, stormwater quality management in urban areas needs to address the lower return period storms for water quality issues as well as the large return period storms (100-year) for flooding.

The hydrologic modeling demonstrated the impact of increased impervious area (development) on stormwater runoff magnitudes. Typical stormwater control measures usually consist of detention structures to control runoff volume and peak flows and design and construction of stable channels. These measures are usually very expensive. An approach that is being implemented in highly urbanized areas is called LID BMPs.

3.3 Low Impact Development

LID reduces the amount of connected impervious area. Connected impervious area refers to flow from impervious surfaces that are hydraulically connected to storm drainage facilities. An impervious area that is not hydraulically connected is rerouted through or over a pervious area so the runoff has an opportunity to infiltrate or be stored naturally on the surface. Keeping impervious areas disconnected hydraulically reduces the effective impervious area and subsequently reduces the increase in runoff. A separate report on LID was prepared to provide information to the City and potential developers. This report is provided in Appendix B.

LID is a comprehensive stormwater management strategy that was developed in Prince George's County, Maryland and is now utilized throughout the United States, Japan, and Germany (Winogradoff, Personal Interview). It presents a new perspective on urban development that integrates site ecological and environmental requirements into all phases of urban planning and design. LID considers the implications of development on a broad scale ranging from the entire watershed to the individual residential lot. The LID approach balances urban development impacts and site design features while increasing lot yields and decreasing development costs, thereby encouraging development and economic growth (Bay Area Stormwater Management Association, 1999).

LID strategies treat stormwater at the source by implementing certain concepts within individual residential lots or entire residential developments. These concepts include:

- Reduced imperviousness
- On-lot storage and infiltration systems
- Functional landscaping
- Open drainage swales
- Flatter slopes
- Increased stormwater runoff travel time (lower velocities and less erosion)
- Enhanced infiltration and depression storage
- Minimized woodland disturbance
- Runoff water conservation and reuse

The utilization of these LID concepts creates a drainage system that, if properly applied and managed, lessens stormwater flow quantities within a watershed. With lower stormwater flows, pollutant loading from lawn fertilizers and septic tanks decrease. Channel erosion and sediment loading within the system are also reduced. This ultimately allows for increased development within a watershed without the cost of expensive and unpopular stormwater retention and detention facilities downstream

(Department of Environmental Resources, 1997). The hydrologic model developed for Wonderland Basin was run to simulate the potential effect of LID. The existing condition model was run with the assumption of LID implementation. The model predicted reduction of peak runoff as much as 35 percent.

One of the project objectives was to work with landowners/developers to design and construct three to five LID projects. This task would consist of providing technical assistance and monetary support for the design and construction of LID projects within either Wonderland or Arrowhead watersheds. Using the Wonderland and Arrowhead drainage boundaries as a guide, landowner information within these basins was obtained from Rapid City and Pennington County. The information obtained included lot ownerships, contact information and lot locations. This information was reviewed to identify potential sites for LID projects. Potential sites included relatively small lots not developed or planning to develop. Developed sites were not included because they would require retrofit applications. Approximately fifteen land owners/developers were contacted. A list of the landowners is provided in Appendix C. From these, we were able to meet several to discuss the concepts of LID and offer an opportunity to implement LID as part of their development. Although LID was accepted as a good idea by each group contacted, none agreed to implement LID into their projects. Based on this effort, it is felt that implementation of LID will require development of ordinances by the City and or County to require LID as a stormwater control alternative. Additionally, it is recommended that the Rapid City Drainage Criteria Manual be amended or updated to incorporate stormwater quality control requirements.

3.4 Public Education Forum

An important component for development of stormwater quality management is and will continue to be, educating the public. As part of this project a public education forum outline was developed. The outline is provided in Appendix D. Open public meetings were held at the City County administration building with specific invitations to the city council members and Rapid City engineering staff. Additionally, a Wonderland basin tour was conducted to show the impacts of increased impervious area and the potential for LID methods. The Mayor, four council members and two city engineering staff attended the Wonderland Basin tour. Although these educational activities were beneficial, no formal action has been taken by the City or County. One component of the education process needs to be documentation of the true cost of development. Currently post-development drainage improvements to provide stormwater control are not fully considered. Continuing public education is important to the development of stormwater control.

IV. BMP Design and Construction

Based on the site assessment, the priority BMP selected for design was an erosion control structure to stabilize the head cut in the main drainage channel. This structure required all of the project funds allocated to construction. The sight survey and erosion control structure design were completed by SDSM&T. Two alternative designs were developed.

The primary difference between the designs were the design peak flow and mannings roughness. The final design selected was based on a peak flow of 650 cfs, which assumes upstream detention in place for future conditions, and a mannings n of 0.06.

The design survey, preliminary design plans and specifications were provided to the City for final design. The City was responsible for final design and preparation of plans and specifications. The preliminary design information plans and specifications provided to the City are presented in Appendix E. The initial cost estimate for the erosion control structure was $72,884. A detailed breakdown of the cost estimate is provided in Table 4.1.

Table 4.1 Preliminary construction cost estimate for Wonderland Basin erosion control structure.

Work item	Unit	Unit cost	Quantity	Total cost
Modilization	LS	$4000	1	$4000
Construction staking	LS	900	1	900
Grubbing	LS	2500	1	2500
Tree Removal:				
6-12 inch	EA	402.71	16	6,443
12-24 inch	EA	466.07	5	2,330
24-30 inch	EA	1,436.36	0	0
Unclassified excavation	CY	13.32	308	4,104
Waste haul	CY	6.00	0	0
Water for embankment	Mgal	18.00	1	18
Gabions with filter fabric	CY	225.00	213	47,925
Seed & fertilizer	SY	0.75	1,361	1,021
Straw mat	SY	2.64	1,361	3,593
Erosion control mesh	SY	4.00	0	0
Silt fence	LF	1.25	40	50
Total Cost				$72,884

The preliminary cost estimate was higher than the allocated construction funds, $65,000. The City was also working on a major utilities improvement project along Park Drive that included the area of the proposed erosion control structure. The City elected to include the erosion control structure as an item within the utility improvement construction project. Due to delays in the utility project, construction of the erosion control BMP was delayed by two years. However, based on the final design by the city and incorporating the construction into the utility improvement project the erosion control structure final construction cost was $65,488.10 which was within 0.7 percent of the construction budget of $65,000.

V. Follow-up Monitoring

As development in the Wonderland Basin has increased since implementation and completion of this project, additional erosion problems have occurred, the City has addressed some of them. It would be difficult and impractical to try to monitor the effect of only the constructed erosion control structure on stormwater quality. Additionally, based on the delay in construction, there is not sufficient funding remaining to develop an adequate monitoring program. However, Wonderland basin has been monitored on a voluntary basis by a graduate class at SDSM&T and will continue to be monitored. This data will be made available.

VI. Summary and Recommendations

The project resulted in a hydrologic analysis of Wonderland Basin which identified the effects of increased impervious area and the potential benefits of implementing BMP's.

A report describing LID practices and their application for stormwater management was prepared and presented to developers, Rapid City Council, and staff of the engineering and planning departments of the City. Implementation will likely require formal adoption into the City's Drainage Criteria Manual.

It is recommended that the City's Drainage Criteria Manual be revised or updated to include stromwater quality management.

Construction of an erosion control structure has been completed and controls channel erosion at a point representing 93 percent of the Wonderland Basin drainage area.

Effective stormwater management in Rapid City must include a significant public education component.

VII. Reference

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Appendix A. Hydrologic Analysis Report

The Affects of Increased Impervious Area on the Quantity of Stormwater Runoff in the Wonderland Drainage Basin

Prepared by:

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November 2000

The Affects of Increased Impervious Area on the Quantity of Stormwater Runoff in the Wonderland Drainage Basin

prepared for

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Rapid City, South Dakota

prepared by

Dan Coon

for fulfillment of

Non-thesis Research Credit (CEE 702)
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November 2000

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introduction

The City of Rapid City, South Dakota, (City) and the South Dakota School of Mines and Technology (SDSM&T) have undertaken a project whose primary goal is to reduce pollutant loading in biologically sensitive stretches of Rapid Creek in west Rapid City, South Dakota (SD). Wonderland Drainage Basin in west Rapid City, SD, has been identified as the basin to be used in this demonstration project. The primary objectives of the project are:

- Finalize the preliminary plan to implement Best Management Practice (BMP) components and low-impact development into the control of stormwater runoff for Wonderland Drainage Basin.
- Conduct public education forums to explain the project and the concept behind low-impact development.
- Design and construct a sediment control facility within the basin.
- Work with landowners/developers to design and construct 3 to 5 low-impact development projects.
- Assess the performance of the Wonderland Drainage Basin demonstration project.

One step in obtaining these objectives is to characterize the stormwater runoff from the Wonderland Drainage Basin for a variety of specified storm events and basin models. This report provides the result of stormwater modeling eighteen storm events and four basin models of the Wonderland Drainage Basin using the Hydrologic Engineering Center- Hydrologic Modeling System (HEC-HMS).

Background

Stormwater management and the issues associated with it are and have been treated as secondary level issues in Rapid City, SD (City). Two prime issues affecting stormwater management have not always been addressed when dealing with stormwater issues and development within the City. These two main issues are 1) the affect of increased impervious area resulting from commercial and residential development on stormwater runoff and 2) the affect of smaller higher frequency storms on the overall basin geomorphology and stormwater runoff quantity and quality.

Increased commercial and residential development in a stormwater basin results in an increase in the amount of impervious area within the basin. The affect of this increase in impervious area on the overall drainage of the basin is often not taken into account when considering areas for development. Often drainage issues are only addressed at or near the boundaries of development. Therefore, a single or combination of developments within a basin can have a large impact on the quantity and quality of stormwater runoff in a basin.

The City has designated the 100- year 2-hour storm event as the major design storm to be addressed in design of many of the components of a stormwater drainage design plan. The use of this less frequent 100-year 2-hour storm event provides a sound basis for development of many of the items with which the City is concerned. These items include factors such as delineation of a flood plain for use in determining areas of potential development and sizing of stormwater drainage structures. Use of the larger storm event allows the City to estimate a conservative development zone and create structures that will handle large storm events. This conservative criterion allows the City to meet one of its primary functions, protection of the lives and property of its citizens. However, use of this storm frequency does not take into account the affects of more frequent smaller storm events on basin geomorphology and stormwater quality.

Field observations indicate that the runoff resulting from the lower frequency storms in developed stormwater basins is increasing in quantity and decreasing in quality. As a basin is developed the amount of impervious area increases. Thus, the amount of stormwater runoff increases for any particular storm event. Therefore, the amount of stormwater runoff that is now seen from a 5-year storm event is greater than that seen for the same storm event before basin development. This increased frequency and quantity of runoff negatively affects basin geomorphology in the form of increased channel erosion and decreased stormwater quality. Consideration of the lower frequency storms in the design and development of stormwater drainage structures will allow for the lessening of the impact of these storms on basin geomorphology and stormwater quality.

One potential way to minimize the impact of development on stormwater quantity and quality is the implementation of Low Impact Development (LID) whenever possible within a drainage basin. LID can, if properly installed, reduce the amount of stormwater runoff from a developed property. This reduced runoff can lessen the impacts of development on basin geomorphology, stormwater quality, and stormwater quantity.

Wonderland Drainage Basin

The Wonderland Drainage Basin is a small urbanized drainage basin located in the western portion of Rapid City, SD. The total basin area is approximately 0.92 square miles (590 acres). The basin predominately consists of single family homes. However, recent development in the basin includes duplexes and multi family homes. There is little if no commercial development in the basin. The basin discharges directly into Rapid Creek. Figure 1 provides the relative location of the Wonderland Drainage Basin in Rapid City, SD.

modeling methods

Computer Model

The computer modeling program used in this study is the Hydrologic Engineering Centers - Hydrologic Modeling System (HEC-HMS). HEC-HMS is the latest version of the U.S. Army Corps of Engineers' Hydrologic Modeling System computer program developed by the Hydrologic Engineering Center (HEC). The program simulates precipitation-runoff and routing processes, both natural and controlled. HEC-HMS is the successor to and replacement for HEC's HEC-1 program and for various specialized versions of HEC-1. HEC-HMS improves upon the capabilities of HEC-1 and provides additional capabilities for distributed modeling and continuous simulation. (Corps)

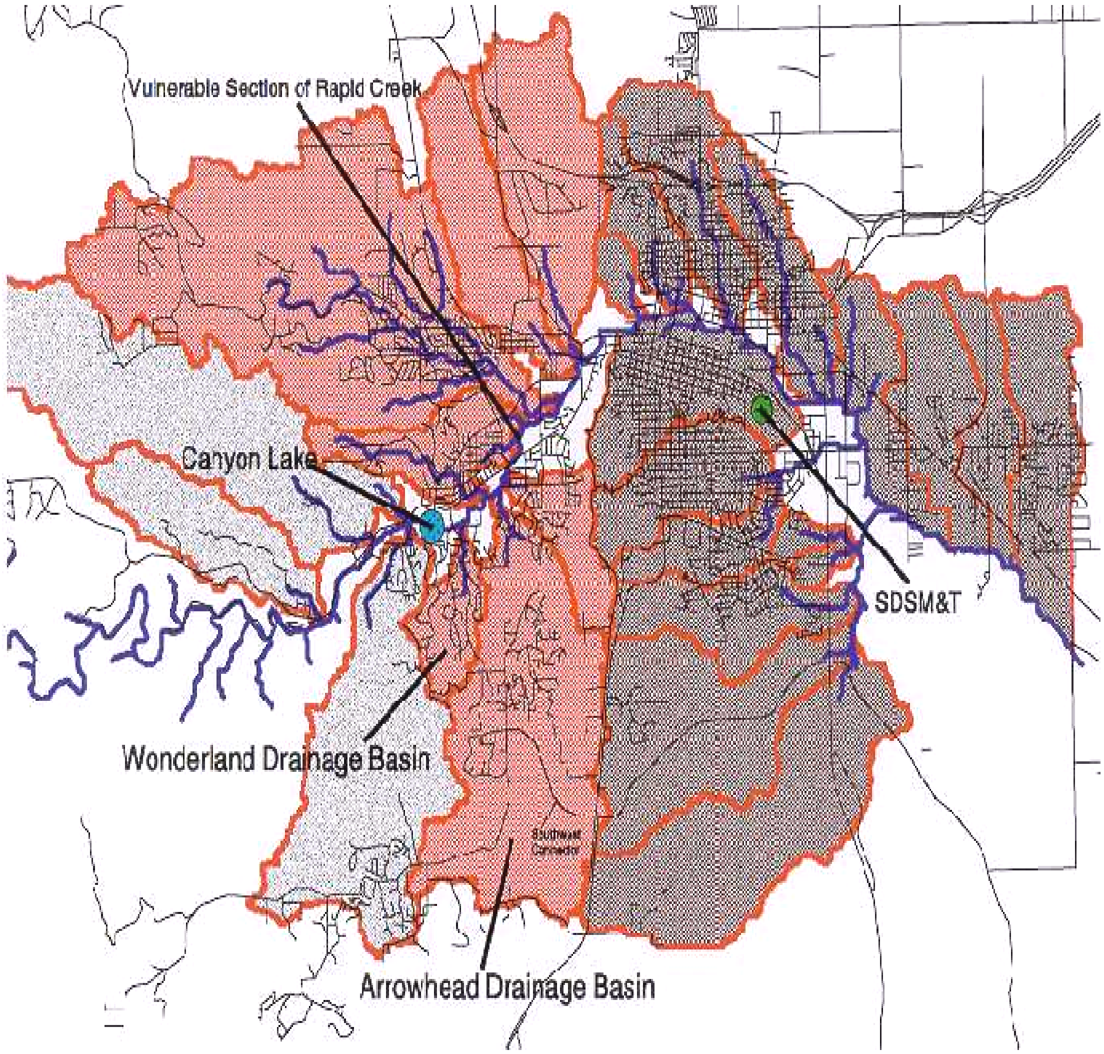

Figure 1 - Location of the Wonderland Drainage Basin

Methods

The following methods were used in compiling the data required for input into the HEC-HMS computer program.

- The Snyder Unit Hydrograph computation method
- The Denver Method for estimating Snyder Unit Hydrograph Parameters
- The Green-Ampt Method to determine infiltration loss
- The Muskingum-Cunge Stream Flow Routing Method

precipitation

Precipitation models for eighteen storm events were developed for input into the HEC-HMS computer program. These eighteen storm events include:

- The 2, 5, 10, 25, 50, and 100-year 2-hour storm events developed using the guidelines contained in the Rapid City, SD Drainage Criteria Manual
- The 2, 5, 10, 25, 50, and 100-year 2-hour storm events and 24-hour storm events developed using National Weather Service (NWS) depth-duration-frequency maps.

The development of design storms in the Rapid City Drainage Criteria Manual is based on research and guidelines developed by the Urban Drainage Flood Control District (UDFCD) for the Denver, CO metropolitan area. The UDFCD studied the rainfall/runoff relationship in the Denver metropolitan area and converted the National Oceanic and Atmospheric Administration (NOAA) Atlas to a family of design rainstorms by distributing the design storm in a manner to reduce reasonable peak recurrence frequency distributions. To obtain a temporal distribution for a design storm in the Denver region, the 1-hour depth is transferred into a 2-hour design storm by multiplying the 1-hour depth(s) by the percentages for each time increment given in Table 2-2 of the Rapid City Drainage Criteria Manual. Design storms can also be developed for the Rapid City area using this same concept. Instead of using the 1-hour rainfall depth for the Denver area, the 1-hour rainfall depth for the Rapid City area is multiplied by the given distribution percentages. (Rapid City) Table 1 provides the 2-hour rainfall distribution for 2, 5, 10, 25, 50, and 100-year frequency storms using the guidelines contained in the Rapid City Drainage Criteria Manual.

The 2, 5, 10, 25, 50, and 100-year 2-hour and 24-hr storm events developed from the NWS depth-duration-frequency maps are also known as frequency based hypothetical design storms. These design storms were developed using precipitation depths from the

Table 1. Wonderland Drainage basin Rapid City 2-hour Storm Distributions.

	2-Year/2-Hour Storm (1-Hour Depth 1.05 in.)			5-Year/2-Hour Storm (1-Hour Depth 1.56 in.)			10-Year/2-Hour Storm (1-Hour Depth 1.86 in.)		
Time (Minutes)	% of 1-Hour Rainfall	Incremental Rainfall	Redistributed Rainfall	% of 1-Hour Rainfall	Incremental Rainfall	Redistributed Rainfall	% of 1-Hour Rainfall	Incremental Rainfall	Redistributed Rainfall
5	2.0	0.02	0.02	2.0	0.03	0.02	2.0	0.04	0.03
10	4.0	0.04	0.04	3.7	0.06	0.05	3.7	0.07	0.05
15	8.4	0.09	0.09	8.7	0.14	0.14	8.2	0.15	0.14
20	16.0	0.17	0.17	15.3	0.24	0.24	15.0	0.28	0.26
25	25.0	0.26	0.26	25.0	0.39	0.39	25.0	0.47	0.44
30	14.0	0.15	0.15	13.0	0.20	0.20	12.0	0.22	0.21
35	6.3	0.07	0.07	5.8	0.09	0.08	5.6	0.10	0.10
40	5.0	0.05	0.05	4.4	0.07	0.06	4.3	0.08	0.08
45	3.0	0.03	0.03	3.6	0.06	0.05	3.8	0.07	0.07
50	3.0	0.03	0.03	3.6	0.06	0.05	3.2	0.06	0.06
55	3.0	0.03	0.03	3.0	0.05	0.04	3.2	0.06	0.06
60	3.0	0.03	0.03	3.0	0.05	0.04	3.2	0.06	0.06
65	3.0	0.03	0.03	3.0	0.05	0.04	3.2	0.06	0.06
70	2.0	0.02	0.02	3.0	0.05	0.04	3.2	0.06	0.06
75	2.0	0.02	0.02	2.5	0.04	0.03	3.2	0.06	0.06
80	2.0	0.02	0.02	2.2	0.03	0.02	2.5	0.05	0.04
85	2.0	0.02	0.02	2.2	0.03	0.02	1.9	0.04	0.03
90	2.0	0.02	0.02	2.2	0.03	0.02	1.9	0.04	0.03
95	2.0	0.02	0.02	2.2	0.03	0.02	1.9	0.04	0.03
100	2.0	0.02	0.02	1.5	0.02	0.01	1.9	0.04	0.03
105	2.0	0.02	0.02	1.5	0.02	0.01	1.9	0.04	0.02
110	2.0	0.02	0.02	1.5	0.02	0.01	1.9	0.04	0.02
115	1.0	0.01	0.01	1.5	0.02	0.01	1.7	0.03	0.02
120	1.0	0.01	0.01	1.3	0.02	0.01	1.3	0.02	0.01
Total	115.7	1.21	1.20	115.7	1.80	1.60	115.7	2.15	1.97

Table 1. Wonderland Drainage basin Rapid City 2-hour Storm Distributions (continued).

	25-Year/2-Hour Storm (1-Hour Depth 2.26 in.)			50-year/2-Hour Storm (1-Hour Depth 2.56 in.)			100-Year/2-Hour Storm (1-Hour Depth 2.95 in.)		
Time (Minutes)	% of 1-Hour Rainfall	Incremental Rainfall	Redistributed Rainfall	% of 1-Hour Rainfall	Incremental Rainfall	Redistributed Rainfall	% of 1-Hour Rainfall	Incremental Rainfall	Redistributed Rainfall
5	2.0	0.05	0.03	1.3	0.03	0.01	1.0	0.03	0.01
10	3.7	0.08	0.06	3.5	0.09	0.07	3.0	0.09	0.07
15	8.2	0.19	0.18	5.0	0.13	0.11	4.6	0.14	0.12
20	15.0	0.34	0.33	8.0	0.20	0.19	8.0	0.24	0.23
25	25.0	0.57	0.56	15.0	0.38	0.37	14.0	0.41	0.40
30	12.0	0.27	0.26	25.0	0.64	0.63	25.0	0.74	0.73
35	5.6	0.13	0.12	12.0	0.31	0.30	14.0	0.41	0.40
40	4.3	0.10	0.09	8.0	0.20	0.19	8.0	0.24	0.23
45	3.8	0.09	0.08	5.0	0.13	0.12	6.2	0.18	0.17
50	3.2	0.07	0.06	5.0	0.13	0.12	5.0	0.15	0.14
55	3.2	0.07	0.06	3.2	0.08	0.07	4.0	0.12	0.11
60	3.2	0.07	0.06	3.2	0.08	0.07	4.0	0.12	0.10
65	3.2	0.07	0.06	3.2	0.08	0.06	4.0	0.12	0.10
70	3.2	0.07	0.06	2.4	0.06	0.04	2.0	0.06	0.04
75	3.2	0.07	0.06	2.4	0.06	0.04	2.0	0.06	0.04
80	2.5	0.06	0.05	1.8	0.05	0.03	1.2	0.04	0.02
85	1.9	0.04	0.03	1.8	0.05	0.03	1.2	0.04	0.02
90	1.9	0.04	0.02	1.4	0.04	0.02	1.2	0.04	0.02
95	1.9	0.04	0.02	1.4	0.04	0.02	1.2	0.04	0.02
100	1.9	0.04	0.02	1.4	0.04	0.02	1.2	0.04	0.02
105	1.9	0.04	0.02	1.4	0.04	0.02	1.2	0.04	0.02
110	1.9	0.04	0.02	1.4	0.04	0.02	1.2	0.04	0.02
115	1.7	0.04	0.02	1.4	0.04	0.02	1.2	0.04	0.02
120	1.3	0.03	0.02	1.4	0.04	0.02	1.2	0.04	0.02
Total	115.7	2.61	2.28	115.6	2.96	2.59	115.6	3.41	3.07

NWS HYDRO-35 and TP-40 maps. Table 2 provides the rainfall distribution for the frequency based hypothetical storms used in this study.

Basin Models

To estimate the impacts of development, and thus the percent of impervious area, within the Wonderland Drainage Basin four basin models were developed. These four basin models estimate the conditions of the Wonderland Drainage Basin at different points in time and with different methods of development. The four basin models developed are:

- Predevelopment Conditions
- Existing Development Conditions
- Predicted Future Development Conditions
- Existing Development Conditions if Low Impact Development (LID) Practices had been used

To predict the stormwater runoff from a drainage basin using HEC-HMS, the modeler must delineate the drainage basin and determine the values for parameters that must be input into the HEC-HMS computer program. For the four basin models identified above, the value of many of the input parameters is the same. The main input parameter changed for each of the programs is the percent impervious area within the basin. Impervious area is that portion of a basin or sub-basin in which there is no infiltration of rainfall. This one critical parameter effects the calculation and value of several other parameters required for input.

HEC-HMS considers that all land and water in a watershed can be categorized as either

- Directly-connected impervious surface; or
- Pervious surface

Table 2. Wonderland Drainage Basin frequency based hypothetical storm distributions.

Storm Frequency/Duration	Depth (Inches)							
	5-Min.	15-Min.	60-Min.	2-Hour	3-Hour	6-Hour	12-Hour	24-Hour
2-Year/2-Hour	0.355	0.68	1.09	1.21	NA	NA	NA	NA
2-Year/24-Hour	0.355	0.68	1.09	1.21	1.35	1.55	1.75	2.1
5-Year/2-Hour	0.45	0.90	1.55	1.65	NA	NA	NA	NA
5-Year/24-Hour	0.45	0.90	1.55	1.65	1.75	2.00	2.30	2.60
10-Year/2-Hour	0.51	1.05	1.86	2.00	NA	NA	NA	NA
10-Year/24-Hour	0.51	1.05	1.86	2.00	2.20	2.50	2.75	3.10
25-Year/2-Hour	0.61	1.26	2.29	2.40	NA	NA	NA	NA
25-Year/24-Hour	0.61	1.26	2.29	2.40	2.60	2.95	3.25	3.60
50-Year/2-Hour	0.68	1.42	2.62	2.70	NA	NA	NA	NA
50-Year/24-Hour	0.68	1.42	2.62	2.70	2.80	3.30	3.40	3.90
100-Year/2-Hour	0.75	1.58	2.95	3.10	NA	NA	NA	NA
100-Year/24-Hour	0.75	1.58	2.95	3.10	3.25	3.60	4.25	4.90

Note: Precipitation Depths obtained from HYDRO-35 and TP-40 maps provided in Appendix E: Rainfall Atlas of ProHEC1 Plus manual.

Directly-connected impervious surface in a drainage basin is that potion of the drainage basin for which all contributing precipitation runs off, with no infiltration, evaporation, or other volume losses. Precipitation on the pervious surfaces is subject to losses. (HEC-HMS)

The following provides a brief description of delineation and development of the input parameters for the Wonderland Drainage Basin. This section is then followed with a description of each of the four basin models.

Input Parameter Development

In development of a basin model the modeler must first delineate the overall basin and then identify and delineate sub-basins within the overall basin. For this study the Wonderland Drainage Basin was divided into 23 sub-basins. Division of a basin into sub-basins provides more control and a higher confidence in the accuracy of results for the modeler. It also provides the modeler with information at various design points within the overall basin. A schematic of the sub-basins and the routing between the sub-basins is provided in Figure 2.

After delineation of the overall basin and sub-basins the modeler must then develop data for the parameters necessary for input into the computer modeling program. These input parameters provide the model with the physical characteristics of each of the sub-basins. The input parameters required by HEC-HMS for each sub-basin are items such as the sub-basin area, the main channel length and slope, the length to centroid, percent impervious area, lag time, and initial rainfall losses. Basin and sub-basin delineation and development of the input parameters is the most critical component of stormwater runoff modeling.

The methodologies, tools, and assumptions that were used as the basis for developing the input parameters for the four basin models is described in more detail in Appendixes A, B, and C.

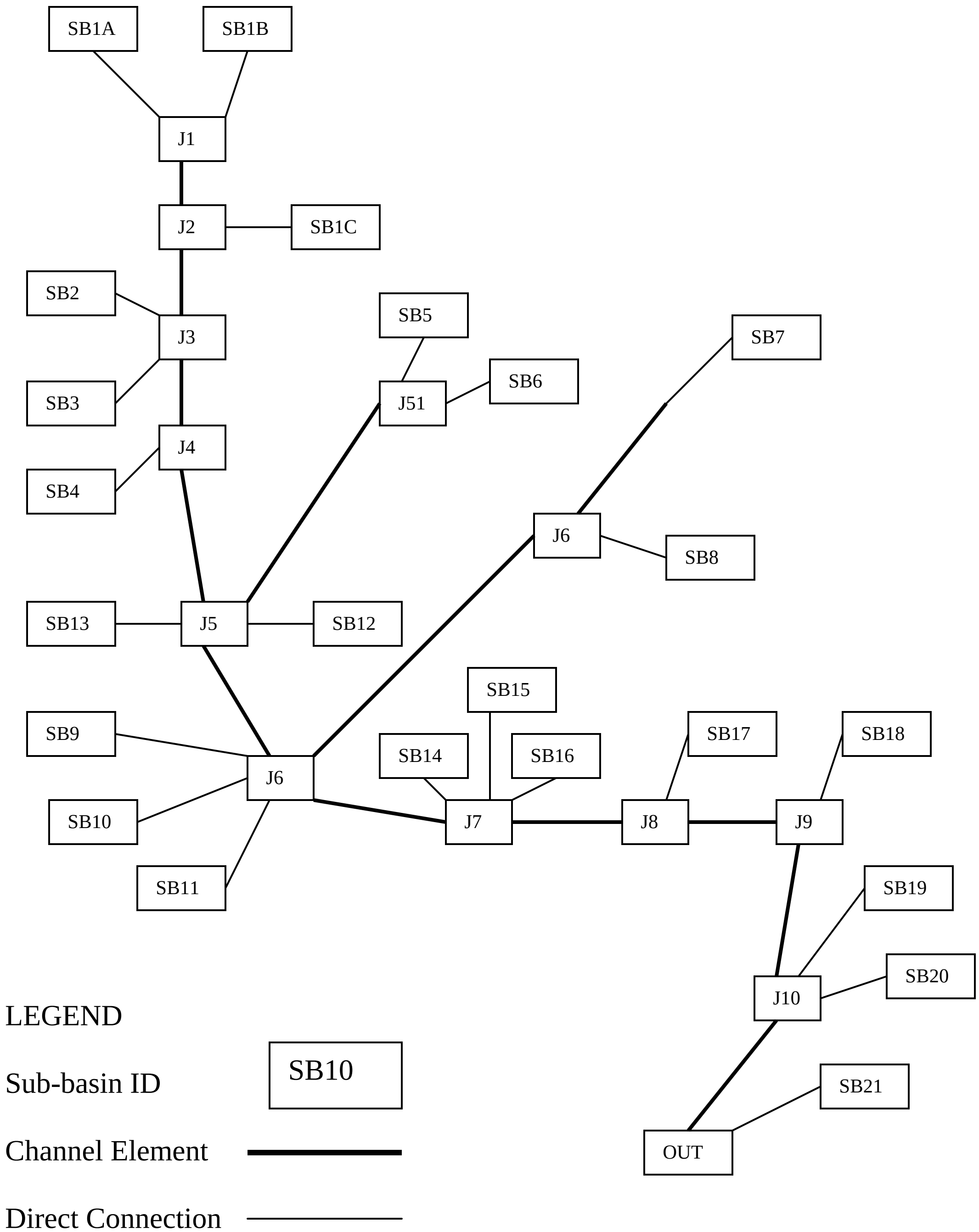

Figure 2. Wonderland Basin sub-basin delineation schematic.

Predevelopment Conditions

The Predevelopment Conditions within the Wonderland Drainage Basin are the conditions within the basin before man affected the basin. This means the basin was in its natural state before man developed roads, houses, parking lots, or other types of impervious areas within the basin. For predevelopment conditions it was assumed that there was 2% naturally occurring impervious area within the basin. This 2% accounts for naturally occurring items in the basin such as rock outcrops, hard packed highly impervious soils, and the affects of dense vegetation within the basin. This 2% impervious area was used for all the sub-basins within the basin. The input parameters whose calculation is affected by the percent impervious area were determined accordingly. Table 3 provides the input parameters used for the Predevelopment Conditions.

Existing Conditions

The Existing Conditions within the Wonderland Drainage Basin are the conditions that existed within the basin at the time of the study and are based on the most recent information and data available. For this study Existing Conditions, specifically percent impervious area, were determined by use of aerial photographs, dated Spring 1997, obtained from the Pennington County Planning Department and site reconnaissance. Appendix A contains a detailed explanation of how percent impervious cover was determined for existing conditions. Those basin parameters whose calculation is affected by percent impervious cover were computed accordingly.

The percent of impervious area for Existing Conditions in the Wonderland Drainage Basin ranged from a minimum of 2.45% for sub-basin SB-1C to a maximum of 30.78% for sub-basin SB-20. The average percent impervious area for Existing Conditions for the overall basin is 15.97%. Table 4 provides the input parameters used for Existing Conditions.

Table 3. Wonderland Drainage Basin parameters for predevelopment conditions.

Sub-Basin	Area (sq. mi.)	Main Channel Length (mi.)	Main Channel Elevation Upper (ft.)	Main Channel Elevation Lower (ft.)	(S) Calculated Channel Slope (ft./ft.)	(S) Modified Channel Slope (ft./ft.)	(Lca) Length to Centroid (mi.)	(Ia) Percent Impervious Cover	Ct	(TL) Lag Time (hrs.)	(P) Peaking Coefficient	Cp
SB-1A	0.025	0.322	3894	3670	0.132	0.060	0.196	2.00	0.156	0.081	2.146	0.192
SB-1B	0.025	0.256	3890	3670	0.163	0.060	0.119	2.00	0.156	0.057	2.146	0.192
SB-1C	0.011	0.145	3670	3620	0.066	0.053	0.085	2.00	0.156	0.038	2.146	0.170
SB-2	0.044	0.511	3864	3540	0.120	0.060	0.289	2.00	0.156	0.122	2.146	0.209
SB-3	0.048	0.568	3856	3486	0.123	0.060	0.321	2.00	0.156	0.135	2.146	0.212
SB-4	0.065	0.524	3790	3486	0.110	0.059	0.282	2.00	0.156	0.123	2.146	0.222
SB-5	0.059	0.619	3788	3470	0.097	0.058	0.265	2.00	0.156	0.129	2.146	0.218
SB-6	0.076	0.739	3774	3470	0.078	0.056	0.420	2.00	0.156	0.177	2.146	0.227
SB-7	0.083	0.530	3756	3480	0.099	0.059	0.272	2.00	0.156	0.121	2.146	0.230
SB-8	0.049	0.504	3746	3464	0.106	0.060	0.275	2.00	0.156	0.118	2.146	0.212
SB-9	0.058	0.552	3632	3424	0.071	0.054	0.373	2.00	0.156	0.147	2.146	0.218
SB-10	0.042	0.491	3551	3424	0.049	NA	0.252	2.00	0.156	0.118	2.146	0.208
SB-11	0.025	0.347	3500	3424	0.042	0.042	0.105	2.00	0.156	0.068	2.146	0.192
SB-12	0.011	0.160	3486	3450	0.043	0.043	0.097	2.00	0.156	0.045	2.146	0.170
SB-13	0.017	0.242	3570	3450	0.094	0.058	0.142	2.00	0.156	0.061	2.146	0.181
SB-14	0.051	0.417	3482	3372	0.050	0.047	0.233	2.00	0.156	0.106	2.146	0.214
SB-15	0.057	0.428	3424	3372	0.023	0.023	0.308	2.00	0.156	0.145	2.146	0.217
SB-16	0.075	0.651	3589	3372	0.063	NA	0.331	2.00	0.156	0.145	2.146	0.226
SB-17	0.035	0.131	3372	3364	0.012	0.012	0.104	2.00	0.156	0.057	2.146	0.202
SB-18	0.009	0.090	3364	3358	0.013	0.013	0.068	2.00	0.156	0.038	2.146	0.165
SB-19	0.003	0.198	3420	3360	0.057	NA	0.068	2.00	0.156	0.039	2.146	0.140
SB-20	0.032	0.379	3472	3360	0.056	NA	0.239	2.00	0.156	0.098	2.146	0.199
SB-21	0.022	0.311	3412	3332	0.049	0.047	0.077	2.00	0.156	0.054	2.146	0.188

Table 4. Wonderland Drainage Basin parameters for existing conditions.

Sub-Basin	Area (sq. mi.)	Main Channel Length (mi.)	Main Channel Elevation Upper (ft.)	Main Channel Elevation Lower (ft.)	(S) Calculated Channel Slope (ft./ft.)	(S) Modified Channel Slope (ft./ft.)	(Lca) Length to Centroid (mi.)	(Ia) Percent Impervious Cover	Ct	(TL) Lag Time (hrs.)	(P) Peaking Coefficient	Cp
SB-1A	0.025	0.293	3880	3670	0.136	0.060	0.196	12.63	0.121	0.061	2.399	0.167
SB-1B	0.025	0.178	3860	3670	0.202	0.060	0.119	9.18	0.129	0.040	2.256	0.167
SB-1C	0.011	0.145	3670	3620	0.066	0.053	0.085	2.45	0.154	0.038	2.145	0.168
SB-2	0.044	0.347	3770	3540	0.126	0.060	0.289	11.91	0.123	0.080	2.365	0.181
SB-3	0.048	0.536	3780	3486	0.104	0.059	0.321	7.26	0.136	0.115	2.202	0.190
SB-4	0.065	0.475	3750	3486	0.105	0.059	0.282	13.40	0.120	0.090	2.439	0.194
SB-5	0.059	0.439	3650	3470	0.078	0.056	0.265	16.01	0.116	0.083	2.596	0.197
SB-6	0.076	0.594	3660	3470	0.061	0.051	0.420	11.30	0.124	0.130	2.337	0.196
SB-7	0.083	0.358	3600	3480	0.063	0.052	0.272	14.51	0.118	0.079	2.501	0.204
SB-8	0.049	0.446	3870	3464	0.173	0.060	0.275	13.00	0.121	0.087	2.418	0.186
SB-9	0.058	0.441	3550	3424	0.054	0.048	0.373	13.84	0.119	0.104	2.463	0.192
SB-10	0.042	0.491	3551	3424	0.049	NA	0.252	15.71	0.116	0.088	2.576	0.187
SB-11	0.025	0.200	3450	3424	0.025	0.025	0.105	20.66	0.110	0.042	2.958	0.186
SB-12	0.011	0.138	3480	3450	0.041	0.041	0.097	13.04	0.121	0.033	2.420	0.149
SB-13	0.017	0.213	3532	3450	0.073	0.054	0.142	17.09	0.114	0.043	2.671	0.166
SB-14	0.051	0.318	3460	3372	0.052	0.047	0.233	16.26	0.116	0.069	2.613	0.193
SB-15	0.057	0.421	3420	3372	0.022	0.022	0.308	16.88	0.115	0.108	2.656	0.198
SB-16	0.075	0.624	3568	3372	0.059	NA	0.331	30.56	0.099	0.091	4.081	0.274
SB-17	0.035	0.131	3372	3364	0.012	0.012	0.104	20.19	0.110	0.040	2.917	0.194
SB-18	0.009	0.090	3364	3358	0.013	0.013	0.068	22.62	0.107	0.026	3.142	0.166
SB-19	0.003	0.198	3420	3360	0.057	NA	0.068	15.54	0.117	0.029	2.565	0.125
SB-20	0.032	0.379	3472	3360	0.056	NA	0.239	30.78	0.099	0.062	4.112	0.243
SB-21	0.022	0.112	3360	3336	0.041	0.041	0.077	14.67	0.118	0.026	2.511	0.167

Future Conditions

The Future Conditions within the Wonderland Drainage Basin are the predicted conditions, specifically impervious area, in the basin after the basin is fully developed. The guidelines for predicting Future Conditions were developed during consultation with personnel from the City of Rapid City and Ferber Engineering Company. These guidelines are:

- Areas within the basin that have ground which slopes between 0% to 10% will be developed with one unit per 10,000 square feet (four units per acre).
- Areas within the basin that have ground which slopes between 10% to 25% will be developed with one unit per acre.
- Areas within the basin that have ground slopes greater than 25% will be developed with one unit per three acres.

Using these guidelines and the residential housing density vs. impervious area criteria given on Figure 2-1 of the Rapid City Drainage Criteria Manual the percent impervious area for the three zones were assumed to be:

- Areas with 0% to 10% slopes will have 42.0% impervious area.
- Areas with 10% to 25% slopes will have 15.0% impervious area.
- Areas with slopes greater than 25% will have 7.0% impervious area.

The percent impervious area for each sub-basin was developed by Ferber Engineering Company using a CADD developed map of the basin and the above criteria. This information was provided for use in this study. The percent of impervious area for Future Conditions in the Wonderland Drainage Basin ranged from a minimum of 9.80% for sub-basin SB-1C to a maximum of 33.20% for sub-basin SB-11. The average impervious area for Future Conditions for the overall basin is 19.80%. Table 5 provides the input parameters used for Future Conditions.

Table 5. Wonderland Drainage Basin parameters for future conditions.

Sub-Basin	Area (sq. mi.)	Main Channel Length (mi.)	Main Channel Elevation Upper (ft.)	Main Channel Elevation Lower (ft.)	(S) Calculated Channel Slope (ft./ft.)	(S) Modified Channel Slope (ft./ft.)	(Lca) Length to Centroid (mi.)	(Ia) Percent Impervious Cover	Ct	(TL) Lag Time (hrs.)	(P) Peaking Coefficient	Cp
SB-1A	0.025	0.322	3894	3670	0.132	0.060	0.196	18.70	0.112	0.059	2.792	0.180
SB-1B	0.025	0.256	3890	3670	0.163	0.060	0.119	14.80	0.118	0.043	2.519	0.171
SB-1C	0.011	0.145	3670	3620	0.066	0.053	0.085	9.80	0.127	0.031	2.278	0.147
SB-2	0.044	0.511	3864	3540	0.120	0.060	0.289	14.10	0.119	0.093	2.478	0.185
SB-3	0.048	0.568	3856	3486	0.123	0.060	0.321	14.30	0.119	0.103	2.489	0.187
SB-4	0.065	0.524	3790	3486	0.110	0.059	0.282	16.00	0.116	0.091	2.595	0.200
SB-5	0.059	0.619	3788	3470	0.097	0.058	0.265	21.20	0.109	0.091	3.007	0.214
SB-6	0.076	0.739	3774	3470	0.078	0.056	0.420	17.40	0.114	0.130	2.693	0.209
SB-7	0.083	0.530	3756	3480	0.099	0.059	0.272	19.90	0.111	0.086	2.891	0.220
SB-8	0.049	0.504	3746	3464	0.106	0.060	0.275	19.80	0.111	0.084	2.883	0.203
SB-9	0.058	0.552	3632	3424	0.071	0.054	0.373	23.90	0.106	0.100	3.273	0.225
SB-10	0.042	0.491	3551	3424	0.049	NA	0.252	17.50	0.114	0.086	2.700	0.191
SB-11	0.025	0.347	3500	3424	0.042	0.042	0.105	33.20	0.097	0.042	4.462	0.249
SB-12	0.011	0.160	3486	3450	0.043	0.043	0.097	19.10	0.112	0.032	2.825	0.160
SB-13	0.017	0.242	3570	3450	0.094	0.058	0.142	22.50	0.107	0.042	3.130	0.182
SB-14	0.051	0.417	3482	3372	0.050	0.047	0.233	27.30	0.102	0.069	3.658	0.239
SB-15	0.057	0.428	3424	3372	0.023	0.023	0.308	22.10	0.108	0.101	3.091	0.217
SB-16	0.075	0.651	3589	3372	0.063	NA	0.331	30.56	0.099	0.092	4.081	0.274
SB-17	0.035	0.131	3372	3364	0.012	0.012	0.104	20.19	0.110	0.040	2.917	0.194
SB-18	0.009	0.090	3364	3358	0.013	0.013	0.068	22.62	0.107	0.026	3.142	0.166
SB-19	0.003	0.198	3420	3360	0.057	NA	0.068	15.54	0.117	0.029	2.565	0.125
SB-20	0.032	0.379	3472	3360	0.056	NA	0.239	30.78	0.099	0.062	4.112	0.243
SB-21	0.022	0.311	3412	3332	0.049	0.047	0.077	14.67	0.118	0.041	2.511	0.167

Existing Conditions with Low Impact Development (LID)

The fourth basin model developed predicts basin conditions, specifically impervious area, if Low Impact Development (LID) techniques had been used from the beginning of basin development to now. LID is a comprehensive stormwater management strategy that treats stormwater at the source. One objective of LID is to lessen stormwater flow quantities within a watershed by use of a variety of development concepts. One of the most effective LID techniques is to minimize directly connected impervious area within a watershed. (Johnson)

To simulate the affects of LID within the basin it was assumed that all stormwater runoff from rooftops was directed to run across a pervious area prior to reaching a stormwater conveyance. By directing rooftop runoff across a pervious area the stormwater has the opportunity to infiltrate into the ground.

For the Existing Conditions Model impervious area was determined by estimating the area of each sub-basin covered by houses and roads. As mentioned, the methods used in determining percent impervious area for Existing Conditions is provided in Appendix A. Hand written notes were kept while determining the percent impervious area within each sub-basin for Existing Conditions. Using these notes the percent of impervious area for houses and roads was known for each sub-basin. If all rooftop runoff is directed to pervious areas, then the percent impervious area within the basin can be attributed mainly to the roads within the basin. Therefore, the square feet of the basin covered by roads was used to determine the percent of impervious area of each sub-basin if LID would have been used.

The percent of impervious area for Existing Conditions if LID had been used in the Wonderland Drainage Basin ranged from a minimum of 2.05% for sub-basin SB-1C to a maximum of 20.56% for sub-basin SB-20. The average impervious area for Existing Conditions with LID for the overall basin is 10.49%. Table 6 provides the input parameters used for Existing Conditions with LID.

Table 6. Wonderland Drainage Basin parameters for existing conditions with LID implemented.

Sub-Basin	Area (sq. mi.)	Main Channel Length (mi.)	Main Channel Elevation Upper (ft.)	Main Channel Elevation Lower (ft.)	(S) Calculated Channel Slope (ft./ft.)	(S) Modified Channel Slope (ft./ft.)	(Lca) Length to Centroid (mi.)	(Ia) Percent Impervious Cover	Ct	(TL) Lag Time (hrs.)	(P) Peaking Coefficient	Cp
SB-1A	0.025	0.322	3894	3670	0.132	0.060	0.196	8.61	0.131	0.068	2.238	0.169
SB-1B	0.025	0.256	3890	3670	0.163	0.060	0.119	3.44	0.150	0.055	2.148	0.186
SB-1C	0.011	0.145	3670	3620	0.066	0.053	0.085	2.05	0.155	0.038	2.146	0.169
SB-2	0.044	0.511	3864	3540	0.120	0.060	0.289	8.19	0.133	0.104	2.226	0.185
SB-3	0.048	0.568	3856	3486	0.123	0.060	0.321	3.81	0.149	0.129	2.150	0.203
SB-4	0.065	0.524	3790	3486	0.110	0.059	0.282	9.64	0.127	0.100	2.272	0.192
SB-5	0.059	0.619	3788	3470	0.097	0.058	0.265	8.30	0.132	0.110	2.229	0.193
SB-6	0.076	0.739	3774	3470	0.078	0.056	0.420	8.28	0.132	0.151	2.229	0.200
SB-7	0.083	0.530	3756	3480	0.099	0.059	0.272	12.49	0.122	0.095	2.392	0.200
SB-8	0.049	0.504	3746	3464	0.106	0.060	0.275	8.78	0.130	0.099	2.244	0.186
SB-9	0.058	0.552	3632	3424	0.071	0.054	0.373	8.35	0.132	0.125	2.231	0.192
SB-10	0.042	0.491	3551	3424	0.049	NA	0.252	14.95	0.118	0.089	2.528	0.185
SB-11	0.025	0.347	3500	3424	0.042	0.042	0.105	13.77	0.120	0.052	2.460	0.169
SB-12	0.011	0.160	3486	3450	0.043	0.043	0.097	7.17	0.136	0.039	2.200	0.153
SB-13	0.017	0.242	3570	3450	0.094	0.058	0.142	11.61	0.123	0.048	2.351	0.157
SB-14	0.051	0.417	3482	3372	0.050	0.047	0.233	10.73	0.125	0.085	2.313	0.184
SB-15	0.057	0.428	3424	3372	0.023	0.023	0.308	9.06	0.129	0.121	2.252	0.190
SB-16	0.075	0.651	3589	3372	0.063	NA	0.331	17.61	0.114	0.106	2.709	0.209
SB-17	0.035	0.131	3372	3364	0.012	0.012	0.104	11.51	0.123	0.045	2.346	0.175
SB-18	0.009	0.090	3364	3358	0.013	0.013	0.068	18.43	0.113	0.028	2.771	0.154
SB-19	0.003	0.198	3420	3360	0.057	NA	0.068	6.58	0.139	0.035	2.187	0.127
SB-20	0.032	0.379	3472	3360	0.056	NA	0.239	20.56	0.110	0.069	2.949	0.193
SB-21	0.022	0.311	3412	3332	0.049	0.047	0.077	10.27	0.125	0.044	2.295	0.162

modeling results

The HEC-HMS stormwater simulation model was run for each of the four basin models using precipitation data for each of the eighteen storms events.

Predevelopment, Existing, and Future Conditions

Storm Event Discharge

Table 7 provides a summary of the stormwater discharge data at the basin outlet for Predevelopment, Existing, and Future Conditions for each of the eighteen storm events. The data provided for each basin model and storm event includes basin discharge (flow) in cubic feet per second (cfs), basin discharge volume in both inches and acre-feet, time to peak discharge from the basin in hours, and where applicable a comparison of the increase in discharge (flow) between comparable basin models.

The comparison of Predevelopment, Existing, and Future Conditions was done between basin models that are adjacent on the basin development timeline. Flow values for Predevelopment Conditions were compared to the flow values for Existing Conditions and Existing Conditions flow values were compared to the flow values for Future Conditions. The increase in flow value was determined by subtracting the flow value from the chronologically previous condition from the adjacent later condition. The percent increase from previous was determined by dividing the increase in flow value by the flow value for the chronologically previous condition.

Each chronologically later basin model represents an increase in the percent impervious area in the Wonderland Drainage Basin. The only factor that has been changed between the models is the percent impervious area and the parameters whose calculation is directly affected by the percent impervious area. A review of the data in Table 7 indicates a direct relationship between the percent impervious area in the basin to the quantity of stormwater runoff from the basin. As percent impervious area increases the quantity of stormwater runoff from the basin increases. However, the data indicates

Table 7. Wonderland Drainage Basin stormwater discharge summary for predevelopment, existing and future conditions.

Storm Event	Predevelopment Conditions			Existing Conditions					Future Conditions				
Rapid City Events	Flow (cfs)	Volume (inches/ac-ft)	Time to Peak (Hr)	Flow (cfs)	Volume (inches/ac-ft)	Time to Peak (Hr)	Increase in Flow (cfs) From Previous	Percent Increase From Previous	Flow (cfs)	Volume (inches/ac-ft)	Time to Peak (Hr)	Increase in Flow (cfs) From Previous	Percent Increase From Previous
2-Yr/2-Hr	9	0.03/1.37	1.25	70	0.20/9.79	1.00	61	677.78%	97	0.26/12.70	1	27	38.57%
5-Yr/2-Hr	80	0.16/8.10	1.00	168	0.39/19.08	0.92	88	110.00%	213	0.47/22.94	0.92	45	26.79%
10-Yr/2-Hr	128	0.25/12.35	0.92	219	0.51/25.30	0.83	91	71.09%	267	0.61/29.93	0.83	48	21.92%
25-Yr/2-Hr	286	0.50/24.76	0.83	368	0.77/38.08	0.83	82	28.67%	424	0.87/42.81	0.83	56	15.22%
50-Yr/2-Hr	464	0.81/40.01	0.92	541	1.09/53.39	0.92	77	16.59%	607	1.18/58.24	0.92	66	12.20%
100-yr/2-Hr	677	1.24/60.97	0.92	743	1.52/74.70	0.92	66	9.75%	821	1.62/79.74	0.92	78	10.50%
Hypothetical Events													
2-Yr/2-Hr	24	0.05/2.69	1.67	91	0.21/10.26	1.58	67	279.17%	122	0.26/12.92	1.58	31	34.07%
2-Yr/24-Hr	96	0.20/9.64	12.58	150	0.42/20.60	12.50	54	56.25%	183	0.50/24.46	12.5	33	22.00%
5-Yr/2-Hr	167	0.30/14.97	1.50	250	0.50/24.77	1.50	83	49.70%	298	0.57/28.23	1.5	48	19.20%
5-Yr/24-Hr	253	0.46/22.45	12.50	311	0.73/35.86	12.50	58	22.92%	356	0.83/40.64	12.42	45	14.47%
10-Yr/2-Hr	319	0.55/27.19	1.50	394	0.78/38.12	1.50	75	23.51%	458	0.86/42.07	1.42	64	16.24%
10-Yr/24-Hr	414	0.73/35.76	12.42	464	1.04/50.90	12.42	50	12.08%	523	1.15/56.38	12.42	59	12.72%
25-Yr/2-Hr	526	0.90/44.13	1.42	594	1.13/55.64	1.42	68	12.93%	668	1.22/59.87	1.42	74	12.46%
25-Yr/24-Hr	610	1.06/52.29	12.42	652	1.40/68.61	12.42	42	6.89%	719	1.52/74.54	12.42	67	10.28%
50-Yr/2-Hr	682	1.16/56.97	1.42	740	1.40/68.83	1.42	58	8.50%	820	1.49/73.19	1.42	80	10.81%
50-Yr/24-Hr	734	1.28/62.95	12.42	772	1.62/79.48	12.42	38	5.18%	845	1.74/85.50	12.42	73	9.46%
100-Yr/2-Hr	854	1.46/72.02	1.42	902	1.72/84.58	1.42	48	5.62%	991	1.81/89.19	1.42	89	9.87%
100-Yr/24-Hr	931	1.68/82.62	12.42	949	2.07/101.97	12.42	18	1.93%	1030	2.22/109.08	12.42	81	8.54%

that the increase in impervious area has the greatest impact on the smaller more frequent storms events.

The greatest impact on the quantity of stormwater runoff is for the 2-year 2-hour storm event developed according to the Rapid City criteria. For Predevelopment Conditions, with 2.0% impervious area, the predicted stormwater runoff for the basin is 9 cfs. For Existing Conditions, with an average of 15.97% impervious area, the flow increases to 70 cfs. This is an increase in flow of 677.78% above Predevelopment Conditions. For Future Conditions with an average of 19.80% impervious area the flow increases to 97 cfs, which is an increase of 38.57% over Existing Conditions.

The impact of percent impervious area on stormwater discharge from the basin deceases as the size and frequency of the design storm increases. The discharge for Predevelopment Conditions for the 100-year 2-hour design storm, developed using the Rapid City criteria, is 677 cfs. For the same storm the predicted stormwater discharge for Existing Conditions is 743 cfs, which is an increase of 9.75% over the Predevelopment Conditions. The predicted discharge for this 100-year 2-hour design storm for Future Conditions is 821 cfs, which is an increase of 10.50% over Existing Conditions.

Figure 3 provides a comparison of the discharge for the six storm events developed using the Rapid City criteria. The storm events listed on the x-axis are for the 2, 5, 10, 25, 50, and 100-year storm events. On Figure 3 the discharge values for the storm events create essentially parallel lines. The distance between the plotted lines varies somewhat but not dramatically. This shows that the difference in discharge values, while similar for each storm event, is a greater percentage of the discharge value for the smaller more frequent storm events.

The lessening of the impact of impervious areas for the larger storm events may be attributed to many factors. One critical factor may be the amount of precipitation lost to infiltration. For a smaller storm event a larger percentage of the available precipitation is lost to infiltration. Precipitation is lost to infiltration during a storm event until the

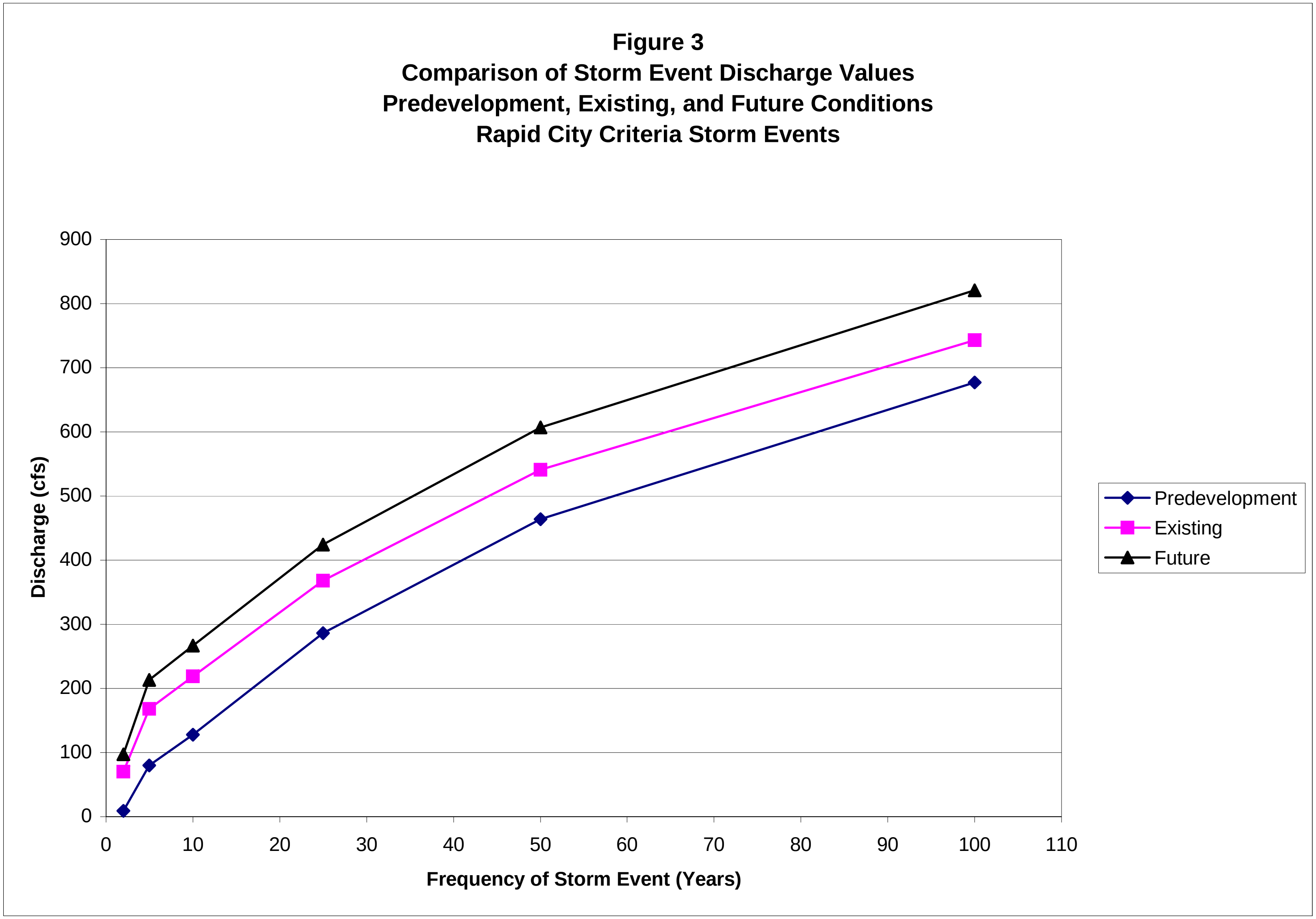
Figure 3
Comparison of Storm Event Discharge Values
Predevelopment, Existing, and Future Conditions
Rapid City Criteria Storm Events
Discharge (cfs)
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60
70
80
90
100
110
Frequency of Storm Event (Years)
Predevelopment
Existing
Future

ground (pervious areas) becomes saturated. After saturation all precipitation from that point forward is available for runoff. Thus, the percentage of total precipitation needed to reach saturation is greater for the smaller storm events than the percentage lost for the larger storm events.

The discharge values and percent difference in values for the hypothetical storm events, as shown on Table 7, has the same trend as that shown for the Rapid City criteria storm events. The effect of the increase in impervious area is greatest on the smaller more frequent storm events, although not to the extent as that shown for the Rapid City criteria storms. Figure 4 and Figure 5 show similar trends for the 2-hour and 24-hour storm events, respectively, as that shown for the Rapid City criteria storms.

This lessening of impact for the hypothetical storm events may be attributed to when the highest intensity of the storm occurs. The Rapid City criteria storms are first quartile storms, meaning that the most intense period of the storm is during the first half-hour or first quartile of the storm. The hypothetical storm events are second quartile storms, meaning the storm intensity peaks halfway through the storm. This may mean that for the first quartile storm, a larger percentage of the precipitation during the highest intensity of the storm is lost to infiltration prior to saturation. Thus, less of the high intensity rainfall is available for runoff. Conversely, during the second quartile storm, infiltration to reach saturation occurs during a lower intensity level of the storm. Thus, a larger percentage of the precipitation is available for runoff.

Time to Peak

Time to Peak is the time from the beginning of the storm event until the peak basin discharge occurs at the basin outlet. Time to peak, in hours, is given on Table 7 for the Predevelopment Conditions, the Existing Conditions, and the Future Conditions for all of the eighteen storm events.

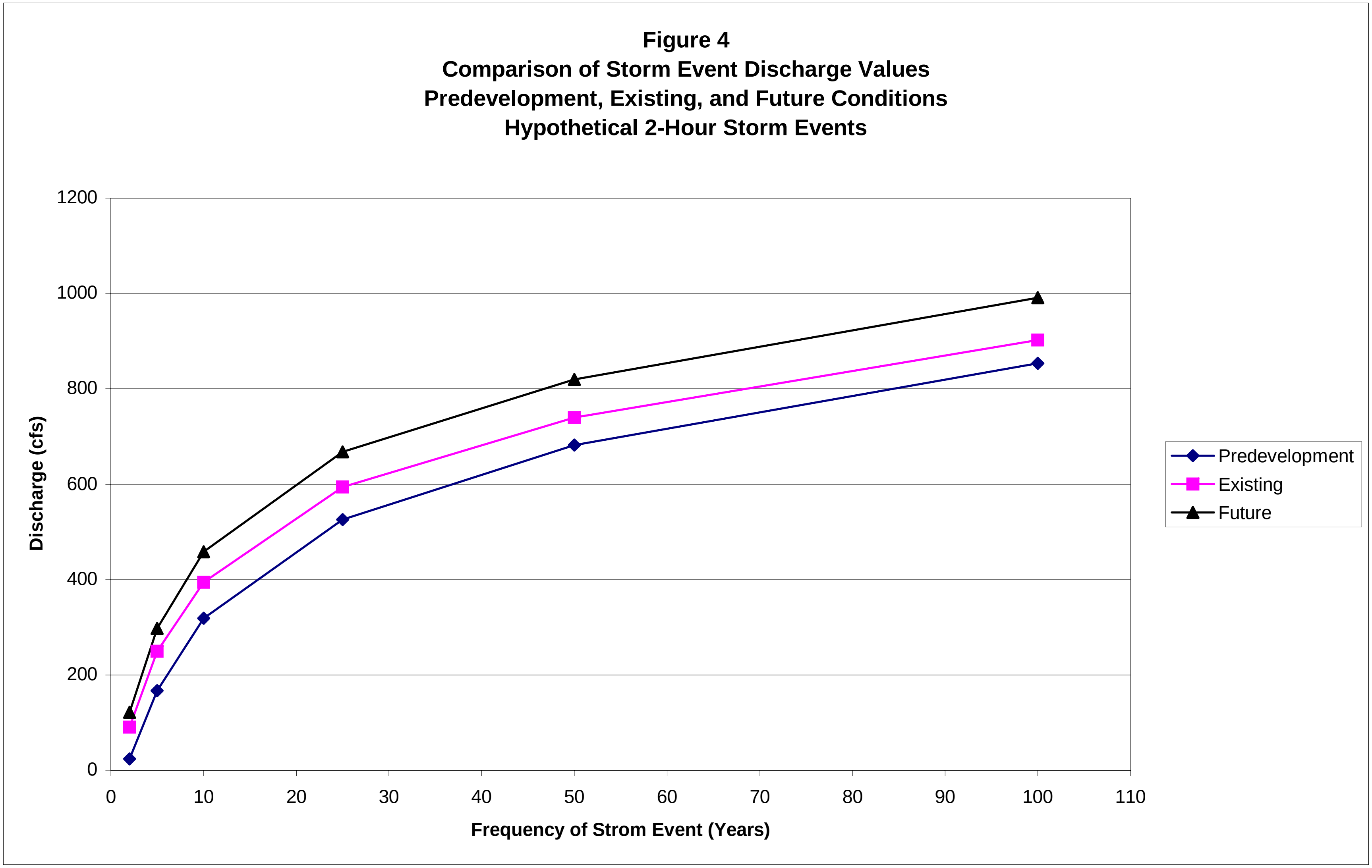

Figure 4
Comparison of Storm Event Discharge Values
Predevelopment, Existing, and Future Conditions
Hypothetical 2-Hour Storm Events
Discharge (cfs)
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
70
80
90
100
110
Frequency of Strom Event (Years)
Predevelopment
Existing
Future

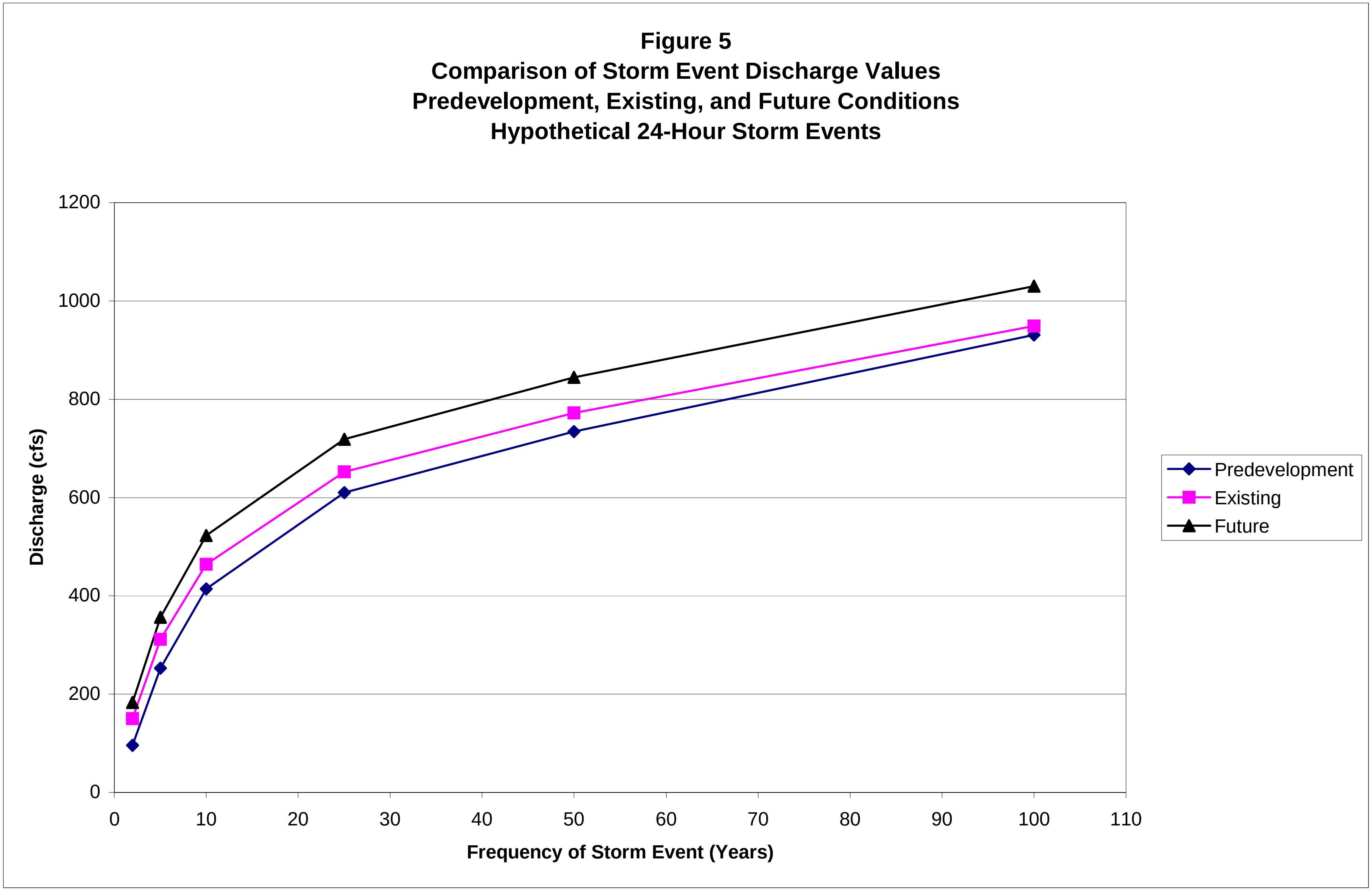
Figure 5
Comparison of Storm Event Discharge Values
Predevelopment, Existing, and Future Conditions
Hypothetical 24-Hour Storm Events
Discharge (cfs)
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
70
80
90
100
110
Frequency of Storm Event (Years)
Predevelopment
Existing
Future

The values given on Table 7 indicate percent impervious area does not have a significant impact on the time to peak for the basin. The greatest difference in Time to Peak is seen between Predevelopment Conditions and Existing Conditions for the 2-year 2-hour Rapid City criteria storm event. This difference is 0.25 hours (15 minutes), which gives a difference of 20.0%. For the remaining storm events the Time to Peak is the same or within 5 minutes of the time to peak for chronologically adjacent basin conditions. This small difference in time to peak for the varied storm events and basin conditions can be attributed to the size of the Wonderland Drainage Basin. The Wonderland Drainage Basin is a relatively small basin. Thus, the response to a storm event will be quick regardless of the size of storm event or variations in basin characteristics.

Existing Conditions and Existing Conditions with LID

Table 8 provides a summary of the stormwater discharge at the basin outlet for the Existing Conditions and the Existing Conditions with LID for each of the eighteen storm events. During computation of the basin models for each of the storm events, HEC-HMS would not compute the hypothetical 5-year 2-hour storm event for the Existing Conditions with LID basin. Therefore, no data is provided on Table 8 for this condition.

Storm Event Discharge

The same categories of data as provided on Table 7 are also provided on Table 8 for the Existing Conditions and Existing Conditions with LID basins. The data indicates results similar to those seen previously. A decrease in percent impervious area results in a decrease in stormwater discharge (flow) from the basin. The effect of the decrease in impervious area is greatest for the smaller more frequent storm events. For the 2-year 2-hour Rapid City criteria storm event the expected discharge from the overall basin for Existing Conditions, with an average impervious area of 15.97%, is 70 cfs. The expected discharge for Existing Conditions with LID, which has an average percent impervious area of 10.49%, for this same storm event is 45 cfs. This is a decrease of 25 cfs or 35.71%.

Table 8. Wonderland Drainage Basin stormwater discharge summary for existing conditions and existing conditions with LID.

Storm Event	Existing Conditions			Use of LID with Existing Conditions				
Rapid City Events	Flow (cfs)	Volume (inches/ac-ft)	Time to Peak (Hr)	Flow (cfs)	Volume (inches/ac-ft)	Time to Peak (Hr)	Increase in Flow (cfs) From Previous	Percent Decrease From Previous
2-Year/2-Hour	70	0.20/9.79	1.00	45	0.13/6.49	1.08	25	35.71%
5-Year/2-Hour	168	0.39/19.08	0.92	129	0.30/14.83	0.92	39	23.21%
10-Year/2-Hour	219	0.51/25.30	0.83	174	0.41/20.27	0.92	45	20.55%
25-Year/2-Hour	368	0.77/38.08	0.83	319	0.67/32.95	0.83	49	13.32%
50-Year/2-Hour	541	1.09/53.39	0.92	486	0.98/48.19	0.92	55	10.17%
100-year/2-Hour	743	1.52/74.70	0.92	681	1.41/69.38	0.92	62	8.34%
Hypothetical Events								
2-Year/2-Hour	91	0.21/10.26	1.58	62	0.15/7.32	1.67	29	31.87%
2-Year/24-Hour	150	0.42/20.60	12.50	124	0.33/16.30	12.58	26	17.33%
5-Year/2-Hour	250	0.50/24.77	1.50					
5-Year/24-Hour	311	0.73/35.86	12.50	276	0.62/30.65	12.50	35	11.25%
10-Year/2-Hour	394	0.78/38.12	1.50	349	0.69/33.89	1.50	45	11.42%
10-Year/24-Hour	464	1.04/50.90	12.42	419	0.91/44.92	12.50	45	9.70%
25-Year/2-Hour	594	1.13/55.64	1.42	537	1.04/51.21	1.42	57	9.60%
25-Year/24-Hour	652	1.40/68.61	12.42	603	1.27/62.23	12.42	49	7.52%
50-Year/2-Hour	740	1.40/68.83	1.42	679	1.31/64.21	1.42	61	8.24%
50-Year/24-Hour	772	1.62/79.48	12.42	718	1.48/73.02	12.42	54	6.99%
100-Year/2-Hour	902	1.72/84.58	1.42	837	1.62/79.69	1.42	65	7.21%
100-Year/24-Hour	949	2.07/101.97	12.42	896	1.92/94.42	12.42	53	5.58%

The percent difference between these two basin conditions decreases as the size and frequency of the storm event increases, much the same as seen for the comparison of the other basin conditions. Figure 6, Figure 7, and Figure 8 provide a graphical comparison of the discharge for the Existing Conditions and the Existing Conditions with LID for the Rapid City criteria and hypothetical storm events. The relationship of the plots is very similar to that seen previously in comparison of the other basins. Note, for Figure 7 no data was plotted for the 5-year 2-hour hypothetical storm event.

Time to Peak

Review of the Time to peak values given on Table 8 indicate that there is little if no effect on the response time of the basin for differing conditions. All Time to Peak values for the Existing Conditions and Existing Conditions with LID basins are the same or within 5 minutes for each of the respective storm events.

affects of Increased Discharge on the Basin

Computer modeling of the stormwater discharge for the four basin conditions and eighteen storm events, conducted for this study, indicate a direct relationship between the percent impervious area of a basin and the quantity of stormwater discharge. As percent impervious area increases within the basin the quantity of stormwater discharge increases for each of the storm events. This concept is not new. However, this study does indicate a dramatic increase in the percentage of discharge for the smaller more frequent storm events.

This effect has been recognized in past studies. A 1975 study conducted by G. E Hollis compiled peak discharge data from 15 previous studies. This data showed a pattern of increasing change in peak discharge with an increase in percentage of impervious area and decreasing storm magnitude. Peak flow increases of two- to three- fold typified the changes brought by low-level suburban development (10 - 20 percent impervious area) on flood peaks with 1 to 10 year recurrence levels. (Booth) These increases in the quantity of discharge are similar to the modeling results in this study.

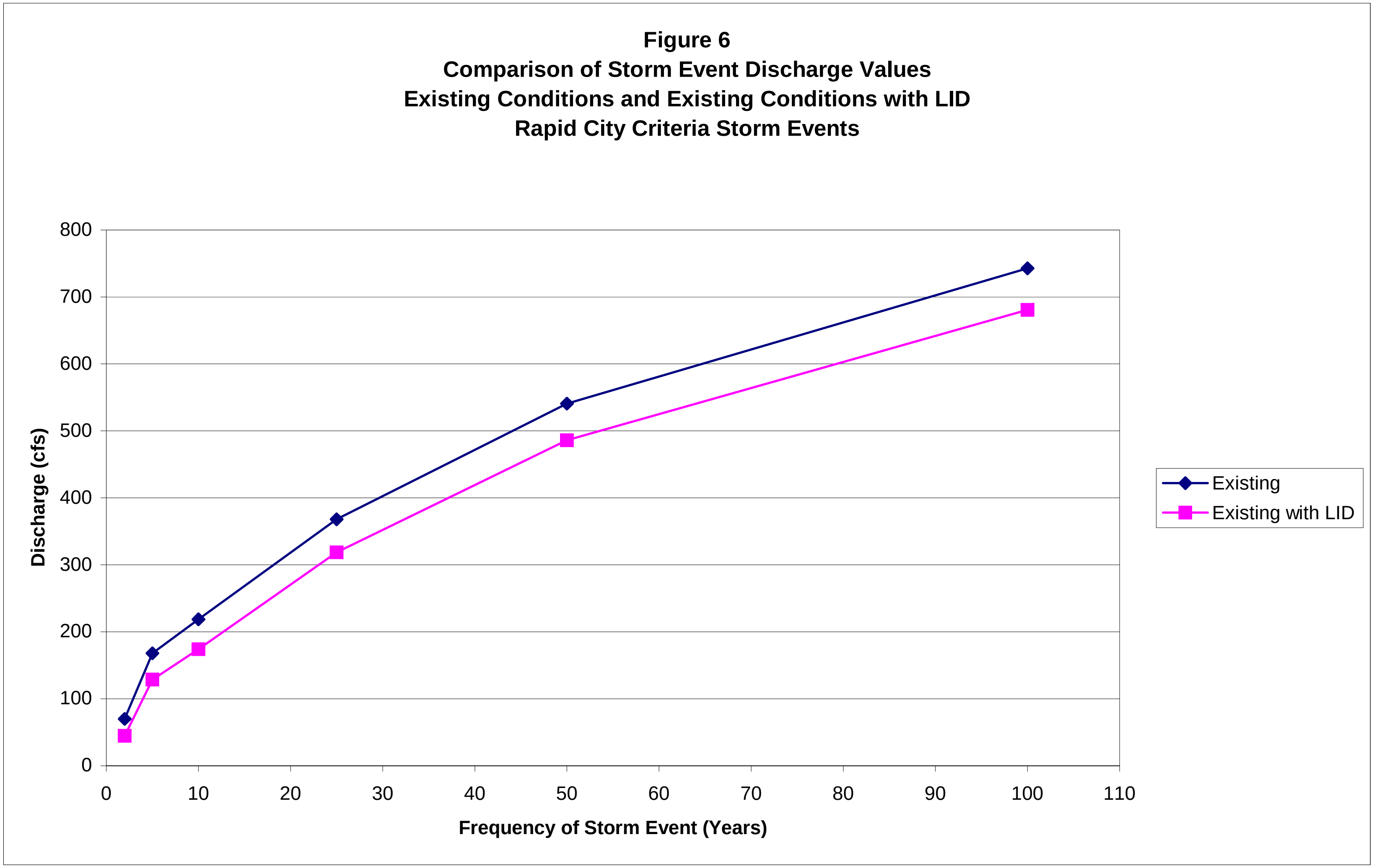
Figure 6
Comparison of Storm Event Discharge Values
Existing Conditions and Existing Conditions with LID
Rapid City Criteria Storm Events
Discharge (cfs)
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
110
Frequency of Storm Event (Years)
Existing
Existing with LID

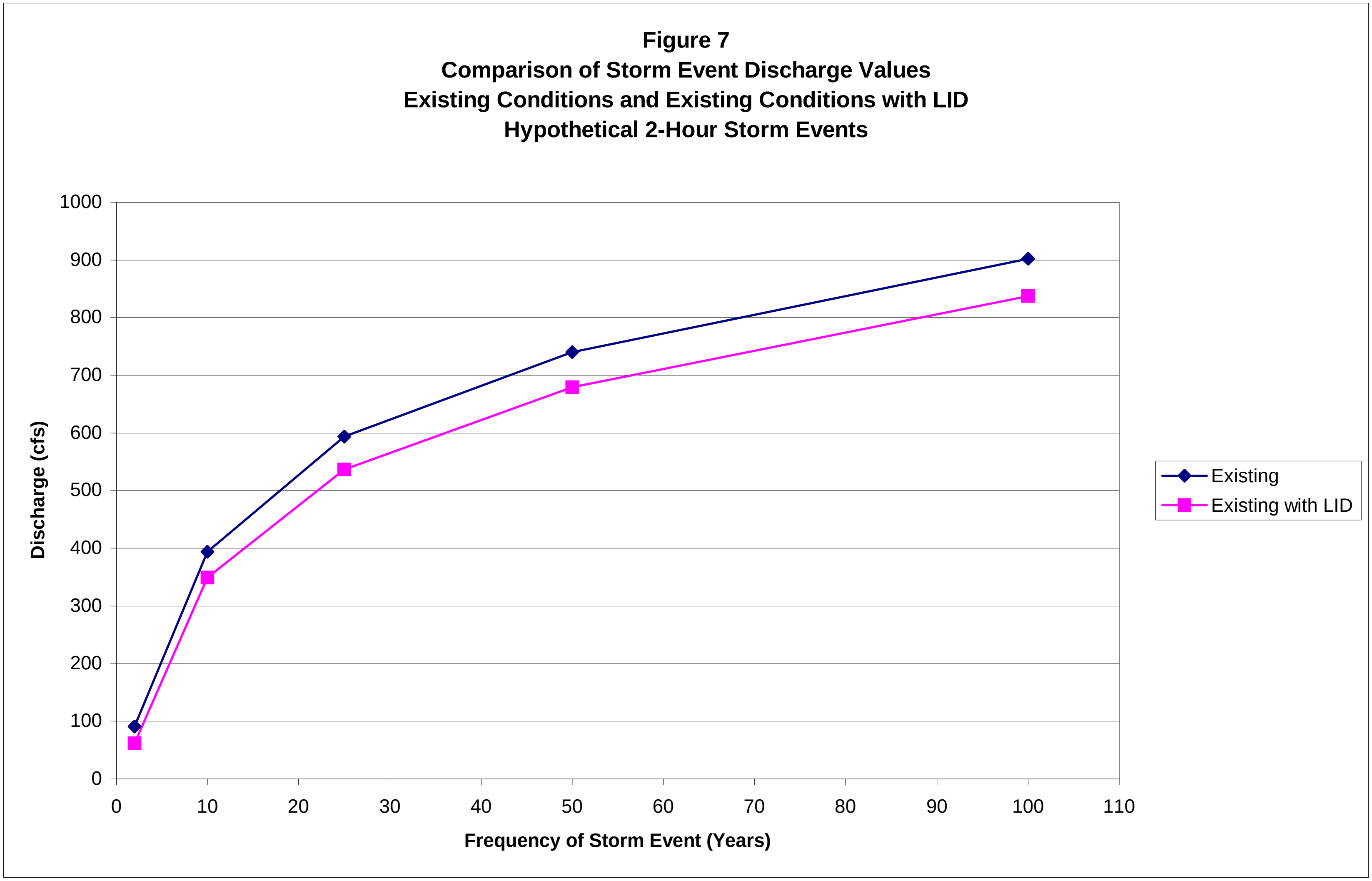
Figure 7
Comparison of Storm Event Discharge Values
Existing Conditions and Existing Conditions with LID
Hypothetical 2-Hour Storm Events
Discharge (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
110
Frequency of Storm Event (Years)
Existing
Existing with LID

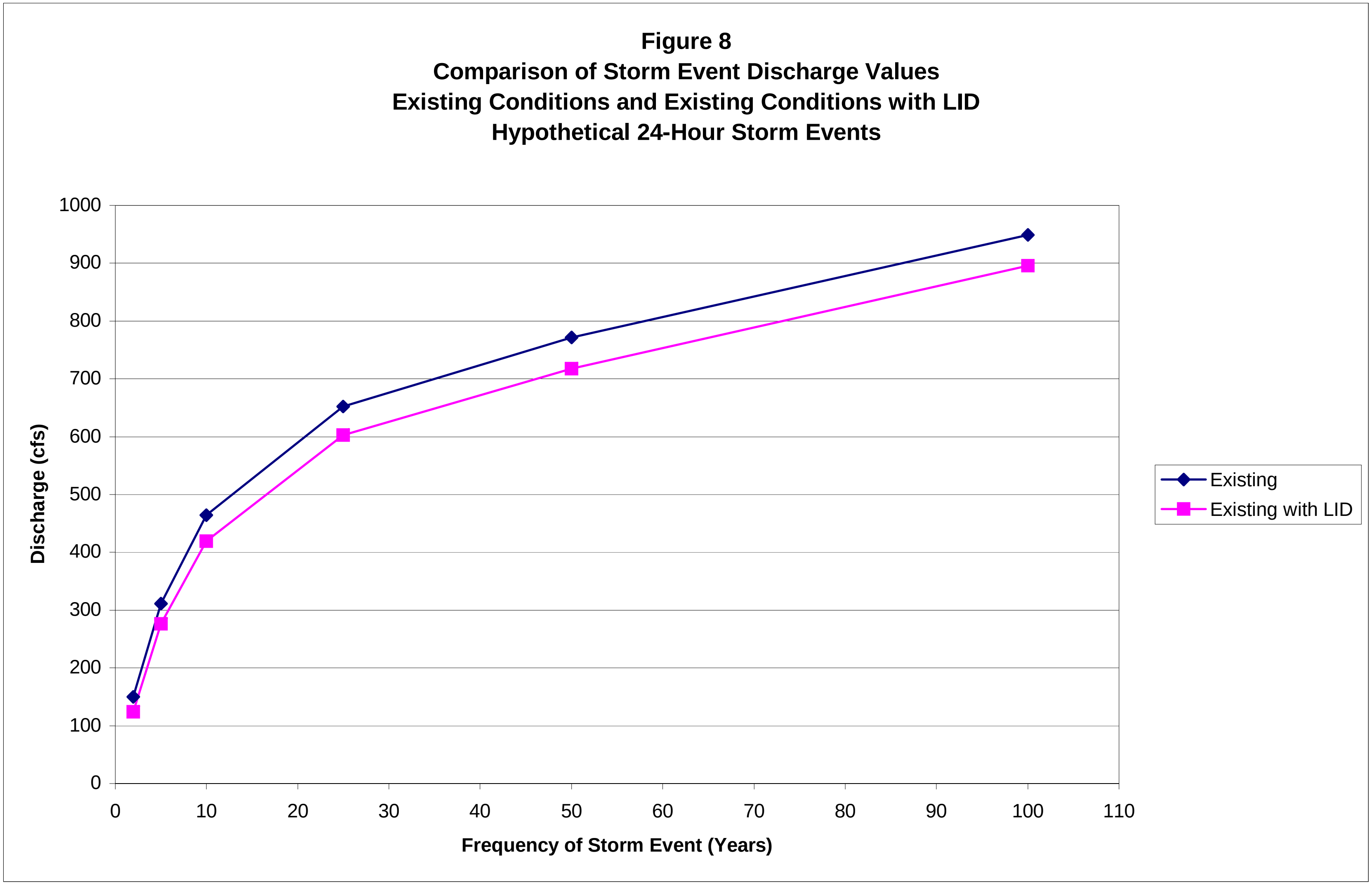
Figure 8
Comparison of Storm Event Discharge Values
Existing Conditions and Existing Conditions with LID
Hypothetical 24-Hour Storm Events
Discharge (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
110
Frequency of Storm Event (Years)
Existing
Existing with LID

Increased discharge from the Wonderland Drainage Basin for the smaller more frequent storm events can result in two interrelated effects; 1) stream channel enlargement, and 2) increase in sediment loading to the receiving stream, in this case Rapid Creek.

Channel Enlargement

As basin urbanization continues the amount of impervious area in the basin will also increase. Therefore, the quantity of stormwater discharge that will be seen for a given storm event will also increase. This means the basin will see larger stormwater discharge on a more frequent basis. For example, the predicted discharge for Existing Conditions for the 2-year 2-hour storm event is 70 cfs. The near equivalent discharge for Predevelopment Conditions is 80 cfs for the 5-year 2-hour storm. This means that the chance of the basin seeing this level of discharge has increase from 20% to almost 50% during a given year.

Basin stormwater channels must respond to increased basin stormwater discharge resulting from increased basin urbanization and the consequent increase in impervious area. This response is usually in the form of channel enlargement which includes both channel incision, defined as rapid channel deepening disproportional to the increase in water discharge, and quasi-equilibrium expansion, where increases in the discharge yield approximately proportional increases in channel width and depth. (Booth)

Review of Manning's equation can provide a simple explanation of the effects of increased discharges on basin channels. Manning's equation for English units is:

$$Q = \frac{1.49}{n}\left(A \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}\right)$$

Where: A = Area of Flow
R = Hydraulic Radius
S = Channel Slope
n = Manning's Roughness Coefficient

Assuming for a given point in a channel Manning's roughness coefficient will not change, then an increase in flow will require the channel to either increase in area and/or increase in slope to reach equilibrium. Both of these effects can be observed in the main channel of the Wonderland Drainage Basin.

Observation of the channel indicates an increase in size of the main drainage channel. However, the effect of increased stormwater discharge can most readily be seen in the changes of channel slope. These changes in channel slope can be observed through three phenomenon:

1) An increase in channel meander within the larger channel floodplain.
2) Channel incision.
3) Development of knick points at susceptible points along the channel.

An increase in channel meander is the result of a channel trying to reach equilibrium by increasing its flow length, thus decreasing its overall slope. Increased meandering has occurred in the main channel of the Wonderland Drainage Basin in reaches were the slope is relatively flat. This meandering has resulted in the channel infringing onto developed sections of the basin resulting in potential damage to existing structures and property.

Incision of the main channel can be seen in Figure 9 and Figure 10. At this point in the channel the channel has tried to reach equilibrium by both deepening and widening of the channel. The channel has eroded to bedrock. Therefore, increased flow in this area will result in continued widening of the channel.

The most dramatic affect of the channel trying to reach equilibrium through a change in slope can be seen in Figure 11. At this location in the channel a large knick point has formed in the channel in soils that have a high susceptibility to erosion. This knick point is approximately 30 feet wide by 4 feet deep and is a result of the channel trying to reach equilibrium by increasing the overall slope of the channel.

Figure 9 - Incision and Widening of the Main Drainage Channel

Figure 10 - Incision and Widening of the Main Channel

Figure 11 - Knick Point in Main Drainage Channel in Lower Portion of the Basin

Sediment Loading

Quantifying the amount of soil that is eroded by an increase in channel area or the incision of the channel is difficult. However, if it is assumed that the amount of sediment the basin stormwater discharge is carrying to the receiving waters increases in direct proportion to the increase in basin stormwater discharge, the amount of sediment loading for each storm event can be estimated.

On September 11, 1999 a stormwater sampling team from the South Dakota School of Mines and Technology collected samples of stormwater discharge from the Wonderland Drainage Basin. The storm event was very minor in precipitation quantity and did not meet the National Pollution Discharge Elimination System (NPDES) requirements for a representative storm event. However, it did provide information that may be representative of minor storm events that are seen in the basin. The quantity of the total suspended solids contained in the stormwater discharge samples was used to determine the Event Mean Concentration (EMC) for suspended solids.

An EMC of 27.82 mg/l for the event results in the predicted total loading as given in Table 9 for each of the predicted basin discharges developed using the Rapid City criteria storm events. In this comparison the greatest impact is seen on the smaller more frequent storm events. This is the same trend that was noted for the increase in discharge from the basin. The greatest increase of 373.72% occurs for the 2-year 2-hour storm event between Predevelopment Conditions and Existing Conditions with LID. A significant increase in total loading of 50.85% is also seen for the 2-year 2-hour storm event between Existing Conditions with LID and Existing Conditions. This simple comparison indicates the effect that the use of LID design and construction techniques could have on the total sediment loading from a basin.

Table 9. Wonderland Drainage Basin potential sediment loading.

Storm Event	Predevelopment Conditions		Existing Conditions with LID			Existing Conditions			Future Conditions		
Rapid City	Volume (ac-ft)	Load (Kg)	Volume (ac-ft)	Load (Kg)	Percent Increase	Volume (ac-ft)	Load (Kg)	Percent Increase	Volume (ac-ft)	Load (Kg)	Percent Increase
2-Year/2-Hour	1.37	47.10	6.49	223.13	373.72%	9.79	336.59	50.85%	12.70	436.64	29.72%
5-Year/2-Hour	8.10	278.49	14.83	509.87	83.09%	19.08	655.99	28.66%	22.94	788.70	20.23%
10-Year/2-Hour	12.35	424.60	20.27	696.90	64.13%	25.30	869.84	24.81%	29.93	1029.02	18.30%
25-Year/2-Hour	24.76	851.27	32.95	1132.85	33.08%	38.08	1309.23	15.57%	42.81	1471.85	12.42%
50-Year/2-Hour	40.01	1375.58	48.19	1656.82	20.44%	53.39	1835.60	10.79%	58.24	2002.35	9.08%
100-Year/2-Hour	60.97	2096.21	69.38	2385.35	13.79%	74.70	2568.26	7.67%	79.74	2741.54	6.75%

Note: Load = ((Volume in ac-ft) x (43,560 cu. ft./ac-ft) x (28.32 Liters/cu. ft.) x (27.87 mg/Liter))/1,000,000 mg/Kg

conclusions

Several conclusions may be drawn from the results of this study.

- The amount of impervious area in a drainage basin has a direct effect on the quantity of stormwater runoff from the drainage basin. This effect is greatest on the predicted stormwater run-off for the smaller more frequent storm events.

- The use of Low Impact Development Techniques could significantly reduce the quantity of stormwater runoff from a drainage basin. This in turn would reduce the effects of increased stormwater runoff on channel degradation and total sediment loading.

- Development within a basin and the resulting increase in impervious area is resulting in the basin seeing increased stormwater discharge more frequently.

- The increased more frequent discharge from the drainage basin has a detrimental effect to basin geomorphology as observed in channel enlargement and incision.

- The increased discharge from the basin increases the sediment carrying capacity of the stormwater discharge. This in turn increases the impact on the receiving stream.

- During development of stormwater basin development plans, modeling should be conducted or at least considered for the smaller more frequent storm events. Development designs should take into account the effects of the smaller more frequent storm events and their affects on the basin and channel geomorphology and potential sediment loading.

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APPENDIXES

CONTENTS OF APPENDIXES

Information concerning the parameters and methodology used in developing the parameters for use in development of the basin models for the Wonderland Drainage Basin watershed model are provided in these appendixes and figures. These include:

- Appendix A - This appendix provides a listing of the sub-basin parameters used for input into HEC-HMS and the methodology and logic used in development of these parameters.

- Appendix B - This appendix provides information on each of the main routing channels between designated junction points within the basin.

- Appendix C - This appendix provides information on the parameters used for precipitation losses for each sub-basin delineated within the Wonderland Drainage Basin.

- Figure 1A - This figure provides the delineated drainage basin and sub-basins of the Wonderland Basin used this study. The base map used for this delineation is a compilation of topographic section maps supplied by the City of Rapid City. This compilation consists of:

  - Section 9, T1N, R7E dated April 29, 1996
  - Section 16, T1N, R7E dated January 18, 1991
  - Section 17, T1N, R7E dated January 18, 1991
  - Section 21, T1N, R7E dated February 28, 1990

- Figure 2A - This figure is a digital orthophoto map showing the extent of development in the Wonderland Drainage Basin. The map was used to help determine the extent of impervious area within each sub-basin. Large scale orthophoto quad maps were available from Pennington county and also used to determine the extend of development within the Wonderland Basin. The specific County maps used were:

  - Pennington County Map No. 37-B dated November 1, 1997
  - Pennington County Map No. 37-E dated November 1, 1997

- Figure 3A - This figure provides information concerning the soil types found within the Wonderland Drainage Basin. The map is the relative portion of Sheet No. 8 found in the Soil Survey of Custer and Pennington Counties, Black Hills Parts, South Dakota.

APPENDIX A

SUB-BASIN PARAMETERS

WONDERLAND DRAINAGE BASIN

APPENDIX A

Sub-basin Parameters

Appendix A provides information on each of the sub-basins delineated within the Wonderland Drainage Basin for the Predevelopment, Existing, Future, and Existing with LID Conditions basin models developed for this study. This information is provided on Tables 1A, 2A, 3A, and 4A located in this appendix.

The following is a description of the methodology used to determine the values for each of the sub-basin parameters listed. While not all the parameters listed are used as input data for HEC-HMS, all are required to determine or calculate input data for the Model. Please note, the information provided on page 2 of each of the above referenced tables is focused for use in determining precipitation losses for the Model. Methodology and a description of these parameters are provided in Appendix C of this report. They are provided on these tables as a convenience for reference to all sub-basin parameters.

All measurements and elevations were obtained directly from the previously described Wonderland Drainage Basin delineation map, a copy of which is provided as Figure 1A.

The following is a description of each parameter (column) on Tables 1A, 2A, 3A, and 4A and the methodology used in determining that parameter.

Area:

Area in square miles of the indicated sub-basin. The area was determined using a planimeter on the sub-basin map. The perimeter of the sub-basin was tracked 3 times. The average of the 3 readings was used as the sub-basin area. If a sub-basin was too large for accurate measurement it was divided into smaller areas. Each smaller area was tracked 3 times and the total of the average of the three measurements for each smaller area was used as the sub-basin area. Planimeter conversion was .633 planimeter units per square inch.

Main Channel Length:

Length of the selected main channel in the sub-basin. The length of each main channel was determined using a map wheel on the sub-basin delineation map (Figure 1A). The main channel within each sub-basin was tracked three times. The average of these measurements was used as the main channel length. The main channel length is provided in both miles and feet. Length in miles is used in determining TL (Lag Time). Length in feet is used in determining channel slope.

Main Channel Elevation (Upper and Lower):

Elevation of the upper and lower ends of the main channel designated for each sub-basin. Elevations were obtained from the sub-basin delineation map (Figure 1A) and were used in calculating the main channel slope.

Calculated Channel Slope (S) and Modified Channel Slope:

Weighted average slope of the sub-basin along the stream (main channel) to the upstream limits of the sub-basin in feet per foot. Subtracting the upper channel elevation from the lower channel elevation and dividing the result by the main channel length determine calculated channel slope. For natural or grass channels with greater than 0.04 ft./ft. slope and without checks the slope was modified per Figure 6.9 on page 6-15 of the ProHEC-1 manual. Channel slope is used in calculating Lag Time (TL).

Length to Centroid

Length along the main channel from the study point to a point along the main channel adjacent to the centroid of the sub-basin in feet and miles. Centroids were determined by using cut-outs of each sub-basin. A string was dangled from three points on the sub-basin cut-out. The intersection of the three lines indicates the centroid.

Percent Impervious Cover (Ia):

Impervious cover was determined using maps of aerial photographs, dated Spring 1997, obtained from the Pennington County Planning Department. Specifically Pennington County Drawing Numbers 37-B and 37-E were obtained. These maps provide a good aerial view of the extent of development in the Wonderland Drainage Basin area as of the Spring of 1997. The original maps are a 1-inch equals 600-ft. scale. To obtain an accurate transcription of the basin delineation, Drawing Number 37-B, which contains the majority of the basin, was enlarged to a 1-inch equals 200 feet scale. This enlarged drawing was placed on vellum paper. The enlarged vellum paper map was placed over the original basin delineation map and with the use of a light table the basin and sub-basins were transposed onto the vellum map. Using the delineation on the enlarged map as a reference the basins and sub-basins were then delineated on the original 1-inch equals 600 feet scale map. This was done because some of the areas of the enlarged map were "washed out" as a result of the enlargement process.

Both the original scale and enlarged scale maps were used to determine impervious area within each sub-basin. Impervious area was determined by estimating the area of each sub-basin covered by houses and roads. Within each sub-basin the dimensions of a minimum of three to five houses were measured, the average of these measurements determined the size of a lot. In more densely developed areas both the house dimensions and driveway dimensions were used to determine a lot size. The number of lots within the sub-basin were then counted, cross-referencing and using both maps. The impervious area covered by houses within the sub-basin was determined by multiplying the lot size by the number of lots.

The impervious area within each sub-basin due to roads was determined by measuring the length of roads in the sub-basin using a map wheel. Then the width of several roads within the sub-basin was measured and an average road width was estimated using these measurements. The impervious area due to roads was calculated by multiplying the measured length by the estimated width. In densely developed areas only the public roads were used to determine impervious area due to roads. Driveways were included in lot impervious area. In sparsely developed areas private driveways, which tend to be longer, were measured and included as roads.

The percentage of impervious area of the sub-basin was then determined by dividing the total impervious area of the sub-basin by the total area within the sub-basin.

A site reconnaissance was conducted on July 27, 1999 to confirm the extent of development along Park Avenue in sub-basins 9, 10 and 15.

Impervious area is used in the calculation of the Ct coefficient, which is used in calculating Lag Time. It is also used in calculating the peaking coefficient P, which is used in calculating peaking coefficient Cp. Hand written notes taken while determining the impervious area for each sub-basin are provided in this appendix after Table 4A.

<u>Coefficient Reflecting Time to Peak (Ct):</u>

Ct is a coefficient reflecting time to peak and represents variations in watershed slopes and storage. It is dependent on the percentage of impervious cover within a sub-basin and is calculated using one of the following, where Ia is percentage of impervious cover.

$Ct = -0.00371(Ia) + 0.163$ $\quad 0 \leq Ia < 10$

$Ct = 0.000023(Ia)^2 - 0.00224(Ia) + 0.146$ $\quad 10 \leq Ia < 40$

$Ct = 0.0000033(Ia)^2 - 0.000801(Ia) + 0.120$ $\quad 40 \leq Ia \leq 100$

<u>Lag Time</u>

Snyder's Standard Lag Time in hours, TP, is determined by the equation:

$$TP = Ct\left(\frac{L \times Lca}{\sqrt{S}}\right)^{0.48}$$

Where:

TL = TP = time to peak of unit hydrograph from midpoint of unit rainfall in hours, e.g., the lag time.

L = length along the stream from the study point to the upstream limits of the basin in miles. (Main Channel Length in miles).

Lca = length along the stream from the study point to a point along the stream adjacent to the centroid of the basin in miles. (Length to Centroid)

S = weighted average slope of the sub-basin along the stream (main channel) to the upstream limits of the subbasin in feet per foot.

Ct = coefficient reflecting time to peak.

Peaking Coefficient (P):

A peaking parameter used to determine Cp. P is calculated using one of the following equations where Ia is percentage of impervious cover.

$$P = 0.002450\,(Ia)^2 - 0.0120(Ia) + 2.16 \qquad 0 \leq Ia \leq 40$$

$$P = -0.00091(Ia)^2 + 0.228(Ia) - 2.06 \qquad 40 < Ia \leq 100$$

Snyder's Peaking Coefficient (Cp):

Cp is a coefficient accounting for flood wave and storage conditions within a sub-basin. It is calculated using:

$$Cp = P \times Ct \times A^{0.15}$$

Where:

Ct = coefficient

A = sub-basin area in square miles

P = peaking parameter

Table 1A. Wonderland Drainage Basin parameters for predevelopment conditions.

Sub-Basin	Area (sq. mi.)	Main Channel Length (mi.)	Main Channel Elevation Upper (ft.)	Main Channel Elevation Lower (ft.)	(S) Calculated Channel Slope (ft./ft.)	(S) Modified Channel Slope (ft./ft.)	(Lca) Length to Centroid (mi.)	(Ia) Percent Impervious Cover	Ct	(TL) Lag Time (hrs.)	(P) Peaking Coefficient	Cp
SB-1A	0.025	0.322	3894	3670	0.132	0.060	0.196	2.00	0.156	0.081	2.146	0.192
SB-1B	0.025	0.256	3890	3670	0.163	0.060	0.119	2.00	0.156	0.057	2.146	0.192
SB-1C	0.011	0.145	3670	3620	0.066	0.053	0.085	2.00	0.156	0.038	2.146	0.170
SB-2	0.044	0.511	3864	3540	0.120	0.060	0.289	2.00	0.156	0.122	2.146	0.209
SB-3	0.048	0.568	3856	3486	0.123	0.060	0.321	2.00	0.156	0.135	2.146	0.212
SB-4	0.065	0.524	3790	3486	0.110	0.059	0.282	2.00	0.156	0.123	2.146	0.222
SB-5	0.059	0.619	3788	3470	0.097	0.058	0.265	2.00	0.156	0.129	2.146	0.218
SB-6	0.076	0.739	3774	3470	0.078	0.056	0.420	2.00	0.156	0.177	2.146	0.227
SB-7	0.083	0.530	3756	3480	0.099	0.059	0.272	2.00	0.156	0.121	2.146	0.230
SB-8	0.049	0.504	3746	3464	0.106	0.060	0.275	2.00	0.156	0.118	2.146	0.212
SB-9	0.058	0.552	3632	3424	0.071	0.054	0.373	2.00	0.156	0.147	2.146	0.218
SB-10	0.042	0.491	3551	3424	0.049	NA	0.252	2.00	0.156	0.118	2.146	0.208
SB-11	0.025	0.347	3500	3424	0.042	0.042	0.105	2.00	0.156	0.068	2.146	0.192
SB-12	0.011	0.160	3486	3450	0.043	0.043	0.097	2.00	0.156	0.045	2.146	0.170
SB-13	0.017	0.242	3570	3450	0.094	0.058	0.142	2.00	0.156	0.061	2.146	0.181
SB-14	0.051	0.417	3482	3372	0.050	0.047	0.233	2.00	0.156	0.106	2.146	0.214
SB-15	0.057	0.428	3424	3372	0.023	0.023	0.308	2.00	0.156	0.145	2.146	0.217
SB-16	0.075	0.651	3589	3372	0.063	NA	0.331	2.00	0.156	0.145	2.146	0.226
SB-17	0.035	0.131	3372	3364	0.012	0.012	0.104	2.00	0.156	0.057	2.146	0.202
SB-18	0.009	0.090	3364	3358	0.013	0.013	0.068	2.00	0.156	0.038	2.146	0.165
SB-19	0.003	0.198	3420	3360	0.057	NA	0.068	2.00	0.156	0.039	2.146	0.140
SB-20	0.032	0.379	3472	3360	0.056	NA	0.239	2.00	0.156	0.098	2.146	0.199
SB-21	0.022	0.311	3412	3332	0.049	0.047	0.077	2.00	0.156	0.054	2.146	0.188

Table 2A. Wonderland Drainage Basin parameters for existing conditions with LID implemented.

Sub-Basin	Area (sq. mi.)	Main Channel Length (mi.)	Main Channel Elevation Upper (ft.)	Main Channel Elevation Lower (ft.)	(S) Calculated Channel Slope (ft./ft.)	(S) Modified Channel Slope (ft./ft.)	(Lca) Length to Centroid (mi.)	(Ia) Percent Impervious Cover	Ct	(TL) Lag Time (hrs.)	(P) Peaking Coefficient	Cp
SB-1A	0.025	0.322	3894	3670	0.132	0.060	0.196	8.61	0.131	0.068	2.238	0.169
SB-1B	0.025	0.256	3890	3670	0.163	0.060	0.119	3.44	0.150	0.055	2.148	0.186
SB-1C	0.011	0.145	3670	3620	0.066	0.053	0.085	2.05	0.155	0.038	2.146	0.169
SB-2	0.044	0.511	3864	3540	0.120	0.060	0.289	8.19	0.133	0.104	2.226	0.185
SB-3	0.048	0.568	3856	3486	0.123	0.060	0.321	3.81	0.149	0.129	2.150	0.203
SB-4	0.065	0.524	3790	3486	0.110	0.059	0.282	9.64	0.127	0.100	2.272	0.192
SB-5	0.059	0.619	3788	3470	0.097	0.058	0.265	8.30	0.132	0.110	2.229	0.193
SB-6	0.076	0.739	3774	3470	0.078	0.056	0.420	8.28	0.132	0.151	2.229	0.200
SB-7	0.083	0.530	3756	3480	0.099	0.059	0.272	12.49	0.122	0.095	2.392	0.200
SB-8	0.049	0.504	3746	3464	0.106	0.060	0.275	8.78	0.130	0.099	2.244	0.186
SB-9	0.058	0.552	3632	3424	0.071	0.054	0.373	8.35	0.132	0.125	2.231	0.192
SB-10	0.042	0.491	3551	3424	0.049	NA	0.252	14.95	0.118	0.089	2.528	0.185
SB-11	0.025	0.347	3500	3424	0.042	0.042	0.105	13.77	0.120	0.052	2.460	0.169
SB-12	0.011	0.160	3486	3450	0.043	0.043	0.097	7.17	0.136	0.039	2.200	0.153
SB-13	0.017	0.242	3570	3450	0.094	0.058	0.142	11.61	0.123	0.048	2.351	0.157
SB-14	0.051	0.417	3482	3372	0.050	0.047	0.233	10.73	0.125	0.085	2.313	0.184
SB-15	0.057	0.428	3424	3372	0.023	0.023	0.308	9.06	0.129	0.121	2.252	0.190
SB-16	0.075	0.651	3589	3372	0.063	NA	0.331	17.61	0.114	0.106	2.709	0.209
SB-17	0.035	0.131	3372	3364	0.012	0.012	0.104	11.51	0.123	0.045	2.346	0.175
SB-18	0.009	0.090	3364	3358	0.013	0.013	0.068	18.43	0.113	0.028	2.771	0.154
SB-19	0.003	0.198	3420	3360	0.057	NA	0.068	6.58	0.139	0.035	2.187	0.127
SB-20	0.032	0.379	3472	3360	0.056	NA	0.239	20.56	0.110	0.069	2.949	0.193
SB-21	0.022	0.311	3412	3332	0.049	0.047	0.077	10.27	0.125	0.044	2.295	0.162

Table 3A. Wonderland Drainage Basin parameters for future conditions.

Sub-Basin	Area (sq. mi.)	Main Channel Length (mi.)	Main Channel Elevation Upper (ft.)	Main Channel Elevation Lower (ft.)	(S) Calculated Channel Slope (ft./ft.)	(S) Modified Channel Slope (ft./ft.)	(Lca) Length to Centroid (mi.)	(Ia) Percent Impervious Cover	Ct	(TL) Lag Time (hrs.)	(P) Peaking Coefficient	Cp
SB-1A	0.025	0.322	3894	3670	0.132	0.060	0.196	18.70	0.112	0.059	2.792	0.180
SB-1B	0.025	0.256	3890	3670	0.163	0.060	0.119	14.80	0.118	0.043	2.519	0.171
SB-1C	0.011	0.145	3670	3620	0.066	0.053	0.085	9.80	0.127	0.031	2.278	0.147
SB-2	0.044	0.511	3864	3540	0.120	0.060	0.289	14.10	0.119	0.093	2.478	0.185
SB-3	0.048	0.568	3856	3486	0.123	0.060	0.321	14.30	0.119	0.103	2.489	0.187
SB-4	0.065	0.524	3790	3486	0.110	0.059	0.282	16.00	0.116	0.091	2.595	0.200
SB-5	0.059	0.619	3788	3470	0.097	0.058	0.265	21.20	0.109	0.091	3.007	0.214
SB-6	0.076	0.739	3774	3470	0.078	0.056	0.420	17.40	0.114	0.130	2.693	0.209
SB-7	0.083	0.530	3756	3480	0.099	0.059	0.272	19.90	0.111	0.086	2.891	0.220
SB-8	0.049	0.504	3746	3464	0.106	0.060	0.275	19.80	0.111	0.084	2.883	0.203
SB-9	0.058	0.552	3632	3424	0.071	0.054	0.373	23.90	0.106	0.100	3.273	0.225
SB-10	0.042	0.491	3551	3424	0.049	NA	0.252	17.50	0.114	0.086	2.700	0.191
SB-11	0.025	0.347	3500	3424	0.042	0.042	0.105	33.20	0.097	0.042	4.462	0.249
SB-12	0.011	0.160	3486	3450	0.043	0.043	0.097	19.10	0.112	0.032	2.825	0.160
SB-13	0.017	0.242	3570	3450	0.094	0.058	0.142	22.50	0.107	0.042	3.130	0.182
SB-14	0.051	0.417	3482	3372	0.050	0.047	0.233	27.30	0.102	0.069	3.658	0.239
SB-15	0.057	0.428	3424	3372	0.023	0.023	0.308	22.10	0.108	0.101	3.091	0.217
SB-16	0.075	0.651	3589	3372	0.063	NA	0.331	30.56	0.099	0.092	4.081	0.274
SB-17	0.035	0.131	3372	3364	0.012	0.012	0.104	20.19	0.110	0.040	2.917	0.194
SB-18	0.009	0.090	3364	3358	0.013	0.013	0.068	22.62	0.107	0.026	3.142	0.166
SB-19	0.003	0.198	3420	3360	0.057	NA	0.068	15.54	0.117	0.029	2.565	0.125
SB-20	0.032	0.379	3472	3360	0.056	NA	0.239	30.78	0.099	0.062	4.112	0.243
SB-21	0.022	0.311	3412	3332	0.049	0.047	0.077	14.67	0.118	0.041	2.511	0.167

Table 4A. Wonderland Drainage Basin parameters for existing conditions with LID implemented.

Sub-Basin	Area (sq. mi.)	Main Channel Length (mi.)	Main Channel Elevation Upper (ft.)	Main Channel Elevation Lower (ft.)	(S) Calculated Channel Slope (ft./ft.)	(S) Modified Channel Slope (ft./ft.)	(Lca) Length to Centroid (mi.)	(Ia) Percent Impervious Cover	Ct	(TL) Lag Time (hrs.)	(P) Peaking Coefficient	Cp
SB-1A	0.025	0.322	3894	3670	0.132	0.060	0.196	8.61	0.131	0.068	2.238	0.169
SB-1B	0.025	0.256	3890	3670	0.163	0.060	0.119	3.44	0.150	0.055	2.148	0.186
SB-1C	0.011	0.145	3670	3620	0.066	0.053	0.085	2.05	0.155	0.038	2.146	0.169
SB-2	0.044	0.511	3864	3540	0.120	0.060	0.289	8.19	0.133	0.104	2.226	0.185
SB-3	0.048	0.568	3856	3486	0.123	0.060	0.321	3.81	0.149	0.129	2.150	0.203
SB-4	0.065	0.524	3790	3486	0.110	0.059	0.282	9.64	0.127	0.100	2.272	0.192
SB-5	0.059	0.619	3788	3470	0.097	0.058	0.265	8.30	0.132	0.110	2.229	0.193
SB-6	0.076	0.739	3774	3470	0.078	0.056	0.420	8.28	0.132	0.151	2.229	0.200
SB-7	0.083	0.530	3756	3480	0.099	0.059	0.272	12.49	0.122	0.095	2.392	0.200
SB-8	0.049	0.504	3746	3464	0.106	0.060	0.275	8.78	0.130	0.099	2.244	0.186
SB-9	0.058	0.552	3632	3424	0.071	0.054	0.373	8.35	0.132	0.125	2.231	0.192
SB-10	0.042	0.491	3551	3424	0.049	NA	0.252	14.95	0.118	0.089	2.528	0.185
SB-11	0.025	0.347	3500	3424	0.042	0.042	0.105	13.77	0.120	0.052	2.460	0.169
SB-12	0.011	0.160	3486	3450	0.043	0.043	0.097	7.17	0.136	0.039	2.200	0.153
SB-13	0.017	0.242	3570	3450	0.094	0.058	0.142	11.61	0.123	0.048	2.351	0.157
SB-14	0.051	0.417	3482	3372	0.050	0.047	0.233	10.73	0.125	0.085	2.313	0.184
SB-15	0.057	0.428	3424	3372	0.023	0.023	0.308	9.06	0.129	0.121	2.252	0.190
SB-16	0.075	0.651	3589	3372	0.063	NA	0.331	17.61	0.114	0.106	2.709	0.209
SB-17	0.035	0.131	3372	3364	0.012	0.012	0.104	11.51	0.123	0.045	2.346	0.175
SB-18	0.009	0.090	3364	3358	0.013	0.013	0.068	18.43	0.113	0.028	2.771	0.154
SB-19	0.003	0.198	3420	3360	0.057	NA	0.068	6.58	0.139	0.035	2.187	0.127
SB-20	0.032	0.379	3472	3360	0.056	NA	0.239	20.56	0.110	0.069	2.949	0.193
SB-21	0.022	0.311	3412	3332	0.049	0.047	0.077	10.27	0.125	0.044	2.295	0.162

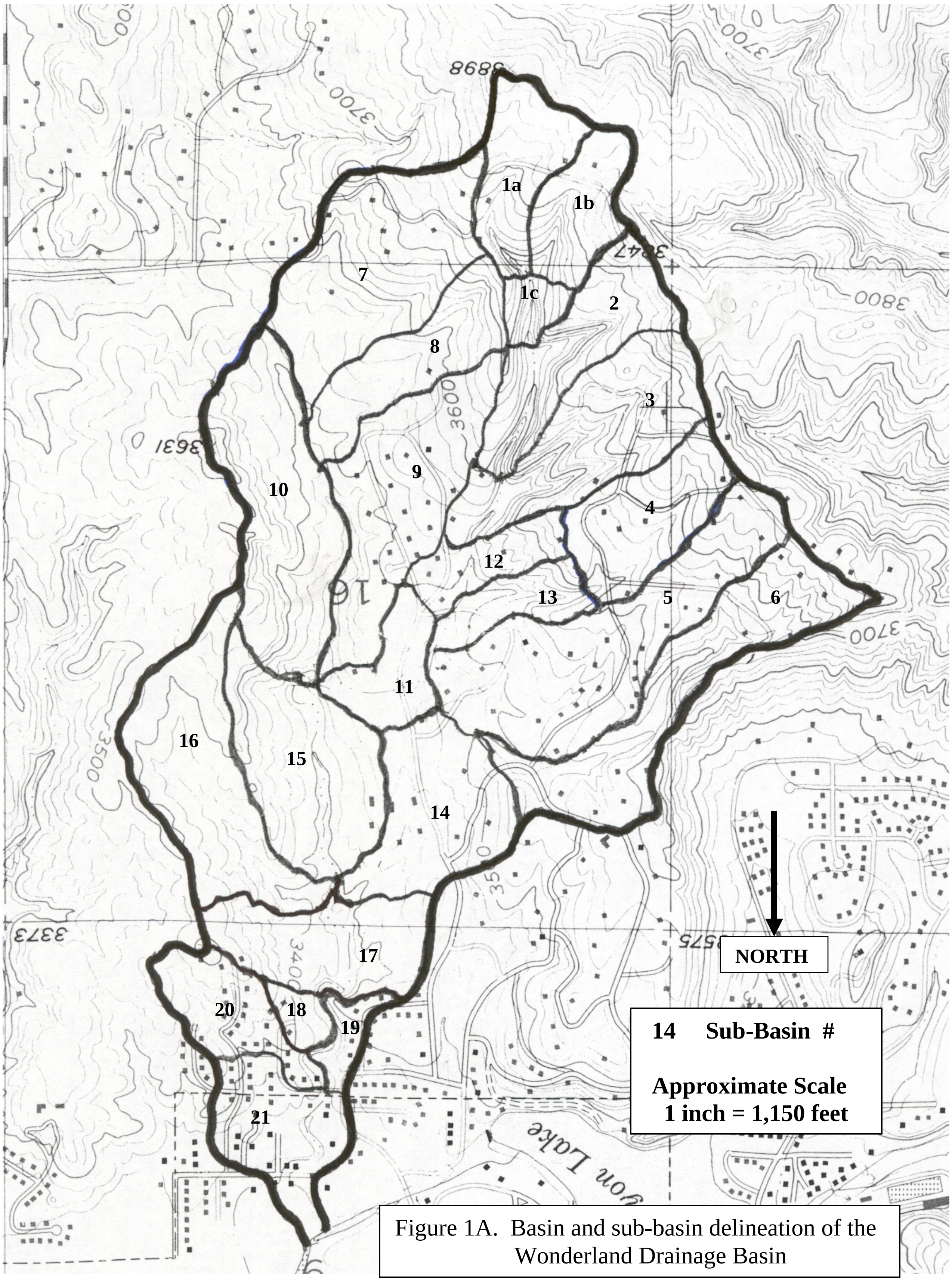

Figure 1A. Basin and sub-basin delineation of the Wonderland Drainage Basin

Figure 2A Extent of basin development in the Wonderland Drainage basin

APPENDIX B

CHANNEL PARAMETERS

WONDERLAND DRAINAGE BASIN

APPENDIX B

Channel Parameters

Appendix B provides information on each of the main routing channels designated between junction points within the Wonderland Drainage Basin. This information is the same for the Predevelopment, Existing, Future, and Existing with LID Conditions basin models and is provided on Table 1B.

The following is a description of the methodology used to determine the values for each of the channel parameters listed. While not all the parameters listed are used as input data for HEC-HMS, all are required to determine or calculate input data for the Model.

All measurements and elevations were obtained directly from the previously described Wonderland Drainage Basin delineation map, a copy of which is provided as Figure 1A.

The following is a description of each parameter (column) on Table 1B and the methodology used in determining that parameter.

<u>Channel Length (L):</u>

Length of the routing channel between designated junction points. The length of each routing channel was determined using a map wheel on the sub-basin map. The routing channel between the designated junction points was tracked three times. The average of these measurements was used as the routing channel length.

<u>Channel Elevation (Upper and Lower):</u>

Elevation of upper and lower ends of the routing channel between the designated junction points. Used in calculating routing channel slope.

<u>Routing Channel Slope (S):</u>

Slope of the designated routing channel. Subtracting the upper channel elevation from the lower channel elevation and dividing the result by the routing channel length determines the routing channel slope.

<u>Channel Roughness (Manning's n):</u>

Used to designate the roughness of the routing channel. Manning's roughness coefficient (n) is used for this parameter. For channels designated as TRAP a Manning's n of 0.050 (designating natural winding stream channels with weeds and pools) is used. For channels in which the eight point method was used the Manning's n for the left overbank, channel, and right overbank are as indicated on the Channel Parameters spreadsheet.

<u>Contributing Area (CA):</u>

Identifies a contributing area to a typical collector that has not been accounted for in hydrographs at the upstream junction point of the designated routing channel. No contributing areas have been identified within the basin.

Channel Shape (SHAPE):

Used to identify the general shape of the routing channel. Three general shapes may be input. They are:

TRAP- Trapezoidal channels, which also includes triangular and rectangular channels.

DEEP- Deep rectangular (square) channels in which flow depth is approximately equal to channel width.

CIRC- Designates a circular channel shape. This cross section only approximates flow in a pipe or culvert. Flow depths are allowed to exceed the pipe diameter.

The eight point method has been used for the main routing channels through the middle of the basin. A general channel shape is not input when using the eight point method.

Channel Bottom Width (WD):

Designates the width or diameter of the bottom of the routing channel. Values used in computer runs of the model were supplied from previous ProHEC-1 Models run on the Wonderland Drainage Basin. This parameter is used in conjunction with a general channel shape such as TRAP. This parameter is not used when using the eight point method.

Channel Side Slopes (Z):

Slope of the sides of the routing channel given as only the horizontal component of a horizontal to vertical (H:V) slope designation where the vertical component is 1. Values used in initial computer runs of the model were supplied from previous ProHEC-1 Models run on the Wonderland Drainage Basin. This parameter is used in conjunction with a general channel shape such as TRAP. This parameter is not used when using the eight point method.

Table 1B Wonderland Drainage Basin channel parameters for all basin models.

Channel Routing	Channel Length (ft.)	Channel Elevation Upper (ft.)	Channel Elevation Lower (ft.)	Routing Channel Slope (ft./ft.)	Manning's n	Contributing Area (CA)	Channel Shape	Channel Bottom Width (WD)	Channel Side Slopes (Z)
J1 to J2	773	3670	3620	0.065	0.05	0	TRAP	15.00	0.50
J2 to J3	1043	3620	3540	0.077	0.05	0	TRAP	10.00	0.50
J3 to J4	1067	3540	3486	0.051	0.05	0	TRAP	25.00	2.00
J4 to J5	937	3486	3450	0.038	0.05	0	TRAP	25.00	2.00
J51 to J5	523	3470	3450	0.038	0.05	0	TRAP	25.00	2.00
J5 to J6	1057	3450	3424	0.025	0.05	0	TRAP	50.00	2.00
SB7 to J62	507	3480	3464	0.032	0.05	0	TRAP	10.00	1.00
J62 to J6	1513	3464	3424	0.026	0.035/0.04/0.035	0	Eight Point	NA	NA
J6 to J7	2337	3424	3372	0.022	0.035/0.04/0.035	0	Eight Point	NA	NA
J7 to J8	747	3372	3364	0.011	0.035/0.04/0.035	0	Eight Point	NA	NA
J8 to J9	473	3364	3352	0.025	0.035/0.04/0.035	0	Eight Point	NA	NA
J9 to J10	383	3352	3350	0.005	0.10/0.04/0.10	0	Eight Point	NA	NA
J10 to Outlet	743	3350	3336	0.019	0.05	0	TRAP	10.00	1.00

Notes:
1. Eight point signifies use of an eight point cross section for the specified routing reach
2. Multiple Manning’s n values are for left overbank, channel and right overbank, respectively.

APPENDIX C

PRECIPITATION LOSSES

WONDERLAND DRAINAGE BASIN

APPENDIX C

Precipitation Losses

Appendix C provides information on the parameters used for precipitation losses for each sub-basin delineated within the Wonderland Drainage Basin for the Predevelopment, Existing, Future, and Existing with LID Conditions basin models developed for this study. This information is provided on Tables 1C, 2C, 3C and 4C located within this appendix.

The following is a description of the methodology used to determine the values for each of the precipitation loss parameters listed. While not all the parameters listed are used as input data for HEC-HMS, all are required to determine or calculate input data for the Model.

The following is a description of each parameter (column) on Tables 1C, 2C, 3C, and 4C the methodology used in determining that parameter.

Soil Type

Designates each of the soil types found in a sub-basin. Soil types were determined using information contained in the "Soil Survey of Custer and Pennington Counties, Black Hills Parts, South Dakota". The approximate location and delineation of the Wonderland Drainage Basin was located on Sheet No. 8 of the soil survey. The basin and sub-basins were not delineated on the soil survey map. The scale of the soil survey map is too small and different from the scale of the basin delineation map to provide a worthwhile representation of the basin. Instead the main drainage channel through the basin was identified on the soil map. (A copy of the soil map with the main channel highlighted is provided as Figure 3A.) The approximate location of each sub-basin was estimated using characteristics of the main channel. From this approximation the type(s) of soils contained in each sub-basin were then noted as listed on the soil survey map.

USDA Texture:

USDA texture for the identified soil type as found in Table 16 - "Engineering Index Properties" in the Soil Survey of Custer and Pennington Counties, Black Hills Parts, South Dakota manual.

Percent In Sub-basin:

Provides an estimate of the percentage of the sub-basin that contains the soil type listed in the previous column.

DTHETA for Soil Type:

The volumetric moisture deficit or effective porosity for the listed USDA soil texture. Values were obtained from Table 5.16 page 5-20 of the ProHec-1 Manual. The average or normal value listed in the table for the soil texture class identified in the USDA Soil Texture column was used.

DTHETA for Sub-basin:

The weighted effective porosity for the listed sub-basin. This value is the sum of the percentage of each soil type found in the sub-basin multiplied by the DTHETA for that soil type. This value is used as the DTHETA for each sub-basin.

PSIF for Soil Type:

The wetted front suction pressure for the USDA soil texture listed for each soil type. Values were obtained from Table 5.16 page 5-20 of the ProHec-1 Manual. The average or normal value listed in the table for the soil texture class identified in the USDA Soil Texture column was used.

PSIF for Sub-basin:

The weighted wetted front suction pressure for the listed sub-basin. This value is the sum of the percentage of each soil type found in the sub-basin multiplied by the PSIF for that soil type. This value is used as the PSIF for each sub-basin. Values are in inches.

XKSAT for Soil Type:

The hydraulic conductivity at natural saturation in inches per hour for the USDA soil texture listed for each soil type. Values were obtained from Table 5.16 page 5-20 of the ProHec-1 Manual.

XKSAT for Sub-basin:

The weighted hydraulic conductivity for the listed sub-basin. This value is the sum of the percentage of each soil type found in the sub-basin multiplied by the XKSAT for that soil type. This value is used as the XKSAT for each sub-basin. Values are in inches per hour.

Percent Impervious Area:

Percentage of impervious area in the sub-basin as previously discussed.

Depression Retention Value:

The depression retention value in inches, for impervious areas as found in Table 2-4 on Page 2-14 of the Rapid City, SD "Drainage Criteria Manual". A value of 0.075 was used for all impervious areas. This is the average of the recommended values found in the table.

Percent Pervious Areas:

The percentage of pervious areas found within the sub-basin. Calculated by subtracting the impervious areas from 100%.

Depression Retention Value:

The depression retention value in inches, for pervious areas as found in Table 2-4 on Page 2-14 of the Rapid City, SD "Drainage Criteria Manual". A value of 0.375 was used for all pervious areas. This is the average of the recommended values found in the table.

Initial Loss (IA):

The initial loss or initial abstraction, in inches, in the sub-basin due mainly to depression storage. The value is the sum of percent impervious area multiplied by the depression retention value for impervious area and the percent pervious area multiplied by the depression retention value for pervious area. This value is used as the IA value for each sub-basin.

Table 1C. Wonderland Drainage Basin precipitation loss parameters for predevelopment conditions.

Sub-Basin	Soil Type	USDA Texture	Percent in Sub-Basin	DTHETA for Soil Type	DTHETA for Sub-Basin	PSIF for Soil Type	PSIF for Sub-Basin	XKSAT for Soil Type	XKSAT for Sub-Basin	Percent Impervious Area	Depression Retention Value (In)	Percent Pervious Areas	Depression Retention Value (In)	IA
SB-1A	SxaE	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	2.00	0.075	98.00	0.375	0.369
SB-1B	SxaE	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	2.00	0.075	98.00	0.375	0.369
SB-1C	HtG	Loamy Sand	1.00	0.401	0.401	2.41	2.41	1.18	1.18	2.00	0.075	98.00	0.375	0.369
SB-2	HtG	Loamy Sand	0.30	0.401		2.41		1.18		2.00	0.075	98.00	0.375	0.369
	SxaE	Silt Loam	0.70	0.486	0.461	6.57	5.32	0.26	0.54					
SB-3	HtG	Loamy Sand	0.60	0.401		2.41		1.18		2.00	0.075	98.00	0.375	0.369
	VkE	Sandy Loam	0.10	0.412		4.33		0.43						
	SxaE	Silt Loam	0.30	0.486	0.428	6.57	3.85	0.26	0.83					
SB-4	NbC	Silt Loam	0.20	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	VkE	Sandy Loam	0.80	0.412	0.427	4.33	4.78	0.43	0.40					
SB-5	NbC	Silt Loam	0.40	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	VkE	Sandy Loam	0.60	0.412	0.442	4.33	5.23	0.43	0.36					
SB-6	TfC	Silt Loam	0.30	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	NbC	Silt Loam	0.60	0.486		6.57		0.26						
	VkE	Sandy Loam	0.10	0.412	0.479	4.33	6.35	0.43	0.28					
SB-7	TfC	Silt Loam	0.30	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	NbC	Silt Loam	0.20	0.486		6.57		0.26						
	SxaE	Silt Loam	0.30	0.486		6.57		0.26						
	VkE	Sandy Loam	0.20	0.412	0.471	4.33	6.12	0.43	0.29					
SB-8	TfC	Silt Loam	0.20	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	NbC	Silt Loam	0.50	0.486		6.57		0.26						
	VkE	Sandy Loam	0.30	0.412	0.464	4.33	5.90	0.43	0.31					
SB-9	TfC	Silt Loam	0.40	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	NbC	Silt Loam	0.60	0.486	0.486	6.57	6.57	0.26	0.26					

Table 1C. Wonderland Drainage Basin precipitation loss parameters for predevelopment conditions. (continued)

Sub-Basin	Soil Type	USDA Texture	Percent in Sub-Basin	DTHETA for Soil Type	DTHETA for Sub-Basin	PSIF for Soil Type	PSIF for Sub-Basin	XKSAT for Soil Type	XKSAT for Sub-Basin	Percent Impervious Area	Depression Retention Value (In)	Percent Pervious Areas	Depression Retention Value (In)	IA
SB-10	TfC	Silt Loam	0.20	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	RfE	Silt Loam/Loam	0.80	0.460	0.465	5.04	5.35	0.20	0.21					
SB-11	TfC	Silt Loam	0.30	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	NbC	Silt Loam	0.70	0.486	0.486	6.57	6.57	0.26	0.26					
SB-12	TfC	Silt Loam	0.10	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	NbC	Silt Loam	0.90	0.486	0.486	6.57	6.57	0.26	0.26					
SB-13	TfC	Silt Loam	0.80	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	NbC	Silt Loam	0.20	0.486	0.486	6.57	6.57	0.26	0.26					
SB-14	TfC	Silt Loam	0.50	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	PcD	Sandy Loam	0.50	0.412	0.449	4.33	5.45	0.43	0.35					
SB-15	TfC	Silt Loam	0.60	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	RfE	Silt Loam/Loam	0.40	0.460	0.476	5.04	5.96	0.20	0.24					
SB-16	RfE	Silt Loam/Loam	1.00	0.460	0.460	5.04	5.04	0.20	0.20	2.00	0.075	98.00	0.375	0.369
SB-17	TfC	Silt Loam	0.20	0.486		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	HnB	Cobbly Loam	0.40	0.434		3.50		0.13						
	RfE	Silt Loam/Loam	0.40	0.460	0.455	5.04	4.73	0.20	0.18					
SB-18	TrB	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	2.00	0.075	98.00	0.375	0.369
SB-19	TrB	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	2.00	0.075	98.00	0.375	0.369
SB-20	TrB	Silt Loam	0.90	0.515		6.57		0.26		2.00	0.075	98.00	0.375	0.369
	CpA	Loam	0.10	0.434	0.507	3.50	6.26	0.13	0.25					
SB-21	CpA	Loam	1.00	0.434	0.434	3.50	3.50	0.13	0.13	2.00	0.075	98.00	0.375	0.369

Table 2C. Wonderland Drainage Basin precipitation loss parameters for existing conditions.

Sub-Basin	Soil Type	USDA Texture	Percent in Sub-Basin	DTHETA for Soil Type	DTHETA for Sub-Basin	PSIF for Soil Type	PSIF for Sub-Basin	XKSAT for Soil Type	XKSAT for Sub-Basin	Percent Impervious Area	Depression Retention Value (In)	Percent Pervious Areas	Depression Retention Value (In)	IA
SB-1A	SxaE	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	12.63	0.075	87.37	0.375	0.337
SB-1B	SxaE	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	9.18	0.075	90.82	0.375	0.347
SB-1C	HtG	Loamy Sand	1.00	0.401	0.401	2.41	2.41	1.18	1.18	2.45	0.075	97.55	0.375	0.368
SB-2	HtG	Loamy Sand	0.30	0.401		2.41		1.18		11.91	0.075	88.09	0.375	0.339
	SxaE	Silt Loam	0.70	0.486	0.461	6.57	5.32	0.26	0.54					
SB-3	HtG	Loamy Sand	0.60	0.401		2.41		1.18		7.26	0.075	92.74	0.375	0.353
	VkE	Sandy Loam	0.10	0.412		4.33		0.43						
	SxaE	Silt Loam	0.30	0.486	0.428	6.57	3.85	0.26	0.83					
SB-4	NbC	Silt Loam	0.20	0.486		6.57		0.26		13.40	0.075	86.60	0.375	0.335
	VkE	Sandy Loam	0.80	0.412	0.427	4.33	4.78	0.43	0.40					
SB-5	NbC	Silt Loam	0.40	0.486		6.57		0.26		16.01	0.075	83.99	0.375	0.327
	VkE	Sandy Loam	0.60	0.412	0.442	4.33	5.23	0.43	0.36					
SB-6	TfC	Silt Loam	0.30	0.486		6.57		0.26		11.30	0.075	88.70	0.375	0.341
	NbC	Silt Loam	0.60	0.486		6.57		0.26						
	VkE	Sandy Loam	0.10	0.412	0.479	4.33	6.35	0.43	0.28					
SB-7	TfC	Silt Loam	0.30	0.486		6.57		0.26		14.51	0.075	85.49	0.375	0.331
	NbC	Silt Loam	0.20	0.486		6.57		0.26						
	SxaE	Silt Loam	0.30	0.486		6.57		0.26						
	VkE	Sandy Loam	0.20	0.412	0.471	4.33	6.12	0.43	0.29					
SB-8	TfC	Silt Loam	0.20	0.486		6.57		0.26		13.00	0.075	87.00	0.375	0.336
	NbC	Silt Loam	0.50	0.486		6.57		0.26						
	VkE	Sandy Loam	0.30	0.412	0.464	4.33	5.90	0.43	0.31					
SB-9	TfC	Silt Loam	0.40	0.486		6.57		0.26		13.84	0.075	86.16	0.375	0.333
	NbC	Silt Loam	0.60	0.486	0.486	6.57	6.57	0.26	0.26					

Table 2C. Wonderland Drainage Basin precipitation loss parameters for existing conditions. (continued)

Sub-Basin	Soil Type	USDA Texture	Percent in Sub-Basin	DTHETA for Soil Type	DTHETA for Sub-Basin	PSIF for Soil Type	PSIF for Sub-Basin	XKSAT for Soil Type	XKSAT for Sub-Basin	Percent Impervious Area	Depression Retention Value (In)	Percent Pervious Areas	Depression Retention Value (In)	IA
SB-10	TfC	Silt Loam	0.20	0.486		6.57		0.26		15.71	0.075	84.29	0.375	0.328
	RfE	Silt Loam/Loam	0.80	0.460	0.465	5.04	5.35	0.20	0.21					
SB-11	TfC	Silt Loam	0.30	0.486		6.57		0.26		20.66	0.075	79.34	0.375	0.313
	NbC	Silt Loam	0.70	0.486	0.486	6.57	6.57	0.26	0.26					
SB-12	TfC	Silt Loam	0.10	0.486		6.57		0.26		13.04	0.075	86.96	0.375	0.336
	NbC	Silt Loam	0.90	0.486	0.486	6.57	6.57	0.26	0.26					
SB-13	TfC	Silt Loam	0.80	0.486		6.57		0.26		17.09	0.075	82.91	0.375	0.324
	NbC	Silt Loam	0.20	0.486	0.486	6.57	6.57	0.26	0.26					
SB-14	TfC	Silt Loam	0.50	0.486		6.57		0.26		16.26	0.075	83.74	0.375	0.326
	PcD	Sandy Loam	0.50	0.412	0.449	4.33	5.45	0.43	0.35					
SB-15	TfC	Silt Loam	0.60	0.486		6.57		0.26		16.88	0.075	83.12	0.375	0.324
	RfE	Silt Loam/Loam	0.40	0.460	0.476	5.04	5.96	0.20	0.24					
SB-16	RfE	Silt Loam/Loam	1.00	0.460	0.460	5.04	5.04	0.20	0.20	30.56	0.075	69.44	0.375	0.283
SB-17	TfC	Silt Loam	0.20	0.486		6.57		0.26		20.19	0.075	79.81	0.375	0.314
	HnB	Cobbly Loam	0.40	0.434		3.50		0.13						
	RfE	Silt Loam/Loam	0.40	0.460	0.455	5.04	4.73	0.20	0.18					
SB-18	TrB	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	22.62	0.075	77.38	0.375	0.307
SB-19	TrB	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	15.54	0.075	84.46	0.375	0.328
SB-20	TrB	Silt Loam	0.90	0.515		6.57		0.26		30.78	0.075	69.22	0.375	0.283
	CpA	Loam	0.10	0.434	0.507	3.50	6.26	0.13	0.25					
SB-21	CpA	Loam	1.00	0.434	0.434	3.50	3.50	0.13	0.13	14.67	0.075	85.33	0.375	0.331

Table 3C. Wonderland Drainage Basin precipitation loss parameters for future conditions.

Sub-Basin	Soil Type	USDA Texture	Percent in Sub-Basin	DTHETA for Soil Type	DTHETA for Sub-Basin	PSIF for Soil Type	PSIF for Sub-Basin	XKSAT for Soil Type	XKSAT for Sub-Basin	Percent Impervious Area	Depression Retention Value (In)	Percent Pervious Areas	Depression Retention Value (In)	IA
SB-1A	SxaE	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	18.70	0.075	81.30	0.375	0.319
SB-1B	SxaE	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	14.80	0.075	85.20	0.375	0.331
SB-1C	HtG	Loamy Sand	1.00	0.401	0.401	2.41	2.41	1.18	1.18	9.80	0.075	90.20	0.375	0.346
SB-2	HtG	Loamy Sand	0.30	0.401		2.41		1.18		14.10	0.075	85.90	0.375	0.333
	SxaE	Silt Loam	0.70	0.486	0.461	6.57	5.32	0.26	0.54					
SB-3	HtG	Loamy Sand	0.60	0.401		2.41		1.18		14.30	0.075	85.70	0.375	0.332
	VkE	Sandy Loam	0.10	0.412		4.33		0.43						
	SxaE	Silt Loam	0.30	0.486	0.428	6.57	3.85	0.26	0.83					
SB-4	NbC	Silt Loam	0.20	0.486		6.57		0.26		16.00	0.075	84.00	0.375	0.327
	VkE	Sandy Loam	0.80	0.412	0.427	4.33	4.78	0.43	0.40					
SB-5	NbC	Silt Loam	0.40	0.486		6.57		0.26		21.20	0.075	78.80	0.375	0.311
	VkE	Sandy Loam	0.60	0.412	0.442	4.33	5.23	0.43	0.36					
SB-6	TfC	Silt Loam	0.30	0.486		6.57		0.26		17.40	0.075	82.60	0.375	0.323
	NbC	Silt Loam	0.60	0.486		6.57		0.26						
	VkE	Sandy Loam	0.10	0.412	0.479	4.33	6.35	0.43	0.28					
SB-7	TfC	Silt Loam	0.30	0.486		6.57		0.26		19.90	0.075	80.10	0.375	0.315
	NbC	Silt Loam	0.20	0.486		6.57		0.26						
	SxaE	Silt Loam	0.30	0.486		6.57		0.26						
	VkE	Sandy Loam	0.20	0.412	0.471	4.33	6.12	0.43	0.29					
SB-8	TfC	Silt Loam	0.20	0.486		6.57		0.26		19.80	0.075	80.20	0.375	0.316
	NbC	Silt Loam	0.50	0.486		6.57		0.26						
	VkE	Sandy Loam	0.30	0.412	0.464	4.33	5.90	0.43	0.31					
SB-9	TfC	Silt Loam	0.40	0.486		6.57		0.26		23.90	0.075	76.10	0.375	0.303
	NbC	Silt Loam	0.60	0.486	0.486	6.57	6.57	0.26	0.26					

Table 3C. Wonderland Drainage Basin precipitation loss parameters for future conditions. (continued)

Sub-Basin	Soil Type	USDA Texture	Percent in Sub-Basin	DTHETA for Soil Type	DTHETA for Sub-Basin	PSIF for Soil Type	PSIF for Sub-Basin	XKSAT for Soil Type	XKSAT for Sub-Basin	Percent Impervious Area	Depression Retention Value (In)	Percent Pervious Areas	Depression Retention Value (In)	IA
SB-10	TfC	Silt Loam	0.20	0.486		6.57		0.26		17.50	0.075	82.50	0.375	0.323
	RfE	Silt Loam/Loam	0.80	0.460	0.465	5.04	5.35	0.20	0.21					
SB-11	TfC	Silt Loam	0.30	0.486		6.57		0.26		33.20	0.075	66.80	0.375	0.275
	NbC	Silt Loam	0.70	0.486	0.486	6.57	6.57	0.26	0.26					
SB-12	TfC	Silt Loam	0.10	0.486		6.57		0.26		19.10	0.075	80.90	0.375	0.318
	NbC	Silt Loam	0.90	0.486	0.486	6.57	6.57	0.26	0.26					
SB-13	TfC	Silt Loam	0.80	0.486		6.57		0.26		22.50	0.075	77.50	0.375	0.308
	NbC	Silt Loam	0.20	0.486	0.486	6.57	6.57	0.26	0.26					
SB-14	TfC	Silt Loam	0.50	0.486		6.57		0.26		27.30	0.075	72.70	0.375	0.293
	PcD	Sandy Loam	0.50	0.412	0.449	4.33	5.45	0.43	0.35					
SB-15	TfC	Silt Loam	0.60	0.486		6.57		0.26		22.10	0.075	77.90	0.375	0.309
	RfE	Silt Loam/Loam	0.40	0.460	0.476	5.04	5.96	0.20	0.24					
SB-16	RfE	Silt Loam/Loam	1.00	0.460	0.460	5.04	5.04	0.20	0.20	30.56	0.075	69.44	0.375	0.283
SB-17	TfC	Silt Loam	0.20	0.486		6.57		0.26		20.19	0.075	79.81	0.375	0.314
	HnB	Cobbly Loam	0.40	0.434		3.50		0.13						
	RfE	Silt Loam/Loam	0.40	0.460	0.455	5.04	4.73	0.20	0.18					
SB-18	TrB	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	22.62	0.075	77.38	0.375	0.307
SB-19	TrB	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	15.54	0.075	84.46	0.375	0.328
SB-20	TrB	Silt Loam	0.90	0.515		6.57		0.26		30.78	0.075	69.22	0.375	0.283
	CpA	Loam	0.10	0.434	0.507	3.50	6.26	0.13	0.25					
SB-21	CpA	Loam	1.00	0.434	0.434	3.50	3.50	0.13	0.13	14.67	0.075	85.33	0.375	0.331

Table 4C. Wonderland Drainage Basin precipitation loss parameters for existing conditions with LID.

Sub-Basin	Soil Type	USDA Texture	Percent in Sub-Basin	DTHETA for Soil Type	DTHETA for Sub-Basin	PSIF for Soil Type	PSIF for Sub-Basin	XKSAT for Soil Type	XKSAT for Sub-Basin	Percent Impervious Area	Depression Retention Value (In)	Percent Pervious Areas	Depression Retention Value (In)	IA
SB-1A	SxaE	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	8.61	0.075	91.39	0.375	0.349
SB-1B	SxaE	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	3.44	0.075	96.56	0.375	0.365
SB-1C	HtG	Loamy Sand	1.00	0.401	0.401	2.41	2.41	1.18	1.18	2.05	0.075	97.95	0.375	0.369
SB-2	HtG	Loamy Sand	0.30	0.401		2.41		1.18		8.19	0.075	91.81	0.375	0.350
	SxaE	Silt Loam	0.70	0.486	0.461	6.57	5.32	0.26	0.54					
SB-3	HtG	Loamy Sand	0.60	0.401		2.41		1.18		3.81	0.075	96.19	0.375	0.364
	VkE	Sandy Loam	0.10	0.412		4.33		0.43						
	SxaE	Silt Loam	0.30	0.486	0.428	6.57	3.85	0.26	0.83					
SB-4	NbC	Silt Loam	0.20	0.486		6.57		0.26		9.64	0.075	90.36	0.375	0.346
	VkE	Sandy Loam	0.80	0.412	0.427	4.33	4.78	0.43	0.40					
SB-5	NbC	Silt Loam	0.40	0.486		6.57		0.26		8.30	0.075	91.70	0.375	0.350
	VkE	Sandy Loam	0.60	0.412	0.442	4.33	5.23	0.43	0.36					
SB-6	TfC	Silt Loam	0.30	0.486		6.57		0.26		8.28	0.075	91.72	0.375	0.350
	NbC	Silt Loam	0.60	0.486		6.57		0.26						
	VkE	Sandy Loam	0.10	0.412	0.479	4.33	6.35	0.43	0.28					
SB-7	TfC	Silt Loam	0.30	0.486		6.57		0.26		12.49	0.075	87.51	0.375	0.338
	NbC	Silt Loam	0.20	0.486		6.57		0.26						
	SxaE	Silt Loam	0.30	0.486		6.57		0.26						
	VkE	Sandy Loam	0.20	0.412	0.471	4.33	6.12	0.43	0.29					
SB-8	TfC	Silt Loam	0.20	0.486		6.57		0.26		8.78	0.075	91.22	0.375	0.349
	NbC	Silt Loam	0.50	0.486		6.57		0.26						
	VkE	Sandy Loam	0.30	0.412	0.464	4.33	5.90	0.43	0.31					
SB-9	TfC	Silt Loam	0.40	0.486		6.57		0.26		8.35	0.075	91.65	0.375	0.350
	NbC	Silt Loam	0.60	0.486	0.486	6.57	6.57	0.26	0.26					

Table 4C. Wonderland Drainage Basin precipitation loss parameters for existing conditions with LID. (continued)

Sub-Basin	Soil Type	USDA Texture	Percent in Sub-Basin	DTHETA for Soil Type	DTHETA for Sub-Basin	PSIF for Soil Type	PSIF for Sub-Basin	XKSAT for Soil Type	XKSAT for Sub-Basin	Percent Impervious Area	Depression Retention Value (In)	Percent Pervious Areas	Depression Retention Value (In)	IA
SB-10	TfC	Silt Loam	0.20	0.486		6.57		0.26		14.95	0.075	85.05	0.375	0.330
	RfE	Silt Loam/Loam	0.80	0.460	0.465	5.04	5.35	0.20	0.21					
SB-11	TfC	Silt Loam	0.30	0.486		6.57		0.26		13.77	0.075	86.23	0.375	0.334
	NbC	Silt Loam	0.70	0.486	0.486	6.57	6.57	0.26	0.26					
SB-12	TfC	Silt Loam	0.10	0.486		6.57		0.26		7.17	0.075	92.83	0.375	0.353
	NbC	Silt Loam	0.90	0.486	0.486	6.57	6.57	0.26	0.26					
SB-13	TfC	Silt Loam	0.80	0.486		6.57		0.26		11.61	0.075	88.39	0.375	0.340
	NbC	Silt Loam	0.20	0.486	0.486	6.57	6.57	0.26	0.26					
SB-14	TfC	Silt Loam	0.50	0.486		6.57		0.26		10.73	0.075	89.27	0.375	0.343
	PcD	Sandy Loam	0.50	0.412	0.449	4.33	5.45	0.43	0.35					
SB-15	TfC	Silt Loam	0.60	0.486		6.57		0.26		9.06	0.075	90.94	0.375	0.348
	RfE	Silt Loam/Loam	0.40	0.460	0.476	5.04	5.96	0.20	0.24					
SB-16	RfE	Silt Loam/Loam	1.00	0.460	0.460	5.04	5.04	0.20	0.20	17.61	0.075	82.39	0.375	0.322
SB-17	TfC	Silt Loam	0.20	0.486		6.57		0.26		11.51	0.075	88.49	0.375	0.340
	HnB	Cobbly Loam	0.40	0.434		3.50		0.13						
	RfE	Silt Loam/Loam	0.40	0.460	0.455	5.04	4.73	0.20	0.18					
SB-18	TrB	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	18.43	0.075	81.57	0.375	0.320
SB-19	TrB	Silt Loam	1.00	0.486	0.486	6.57	6.57	0.26	0.26	6.58	0.075	93.42	0.375	0.355
SB-20	TrB	Silt Loam	0.90	0.515		6.57		0.26		20.56	0.075	79.44	0.375	0.313
	CpA	Loam	0.10	0.434	0.507	3.50	6.26	0.13	0.25					
SB-21	CpA	Loam	1.00	0.434	0.434	3.50	3.50	0.13	0.13	10.27	0.075	89.73	0.375	0.344

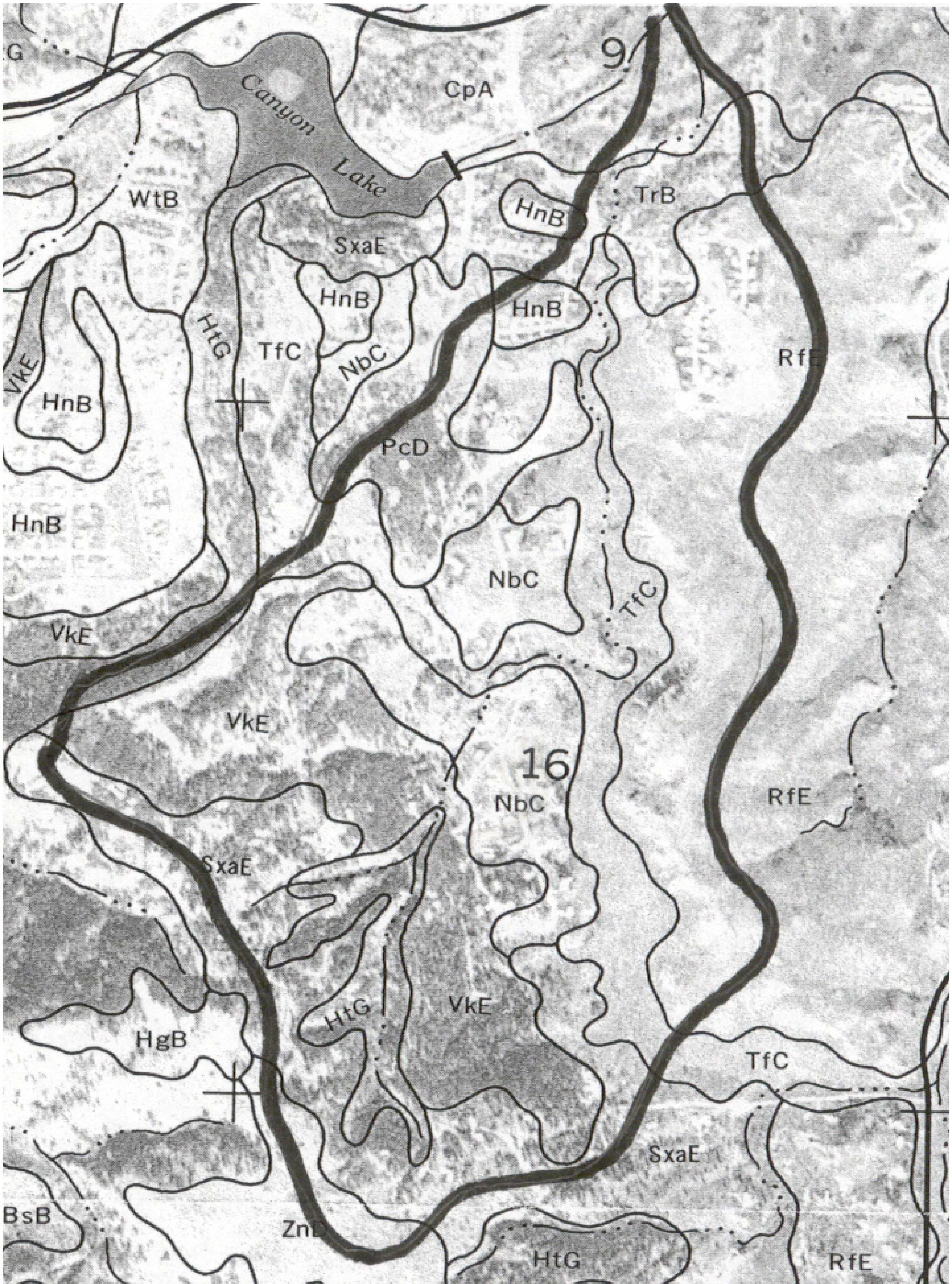

Figure 3A. Soil mapping for the Wonderland Drainage Basin.

Appendix B. Low Impact Development Report

Low-Impact Development

A Potential Stormwater Management Solution for Rapid City, South Dakota

Prepared by
Jeromy Johnson
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September, 1999

Abstract

Rapid City has a tremendous natural resource in Rapid Creek. The stream provides the city with an excellent water source, recreational opportunities, and is home to one of the only Blue Ribbon trout fisheries in the state. However, the potential now exists for development within Rapid City to degrade the health of Rapid Creek to the point of no return. Because of the soil disturbance and increased imperviousness associated with new development, stormwater flows within our watersheds will increase in quantity and decrease in quality unless a stormwater quality management plan is implemented. This is particularly true in the southwest area of Rapid City, which has seen tremendous growth the past ten years and will continue to see growth with the completion of the Southwest Connector.

In November 2002, Phase II of the Stormwater Regulations within the Clean Water Act will become law. This law will require all communities with a population over 10,000 residents to develop, implement, and enforce a comprehensive stormwater quality management plan for each watershed within its boundaries. Rapid City currently does not have a comprehensive plan for controlling the quality of stormwater within its watersheds. This report provides an overview of a partial solution to Rapid City's potential stormwater quality dilemma. This partial solution is Low-Impact Development. Ultimately, the implementation of Low-Impact Development strategies, in conjunction with traditional stormwater management concepts, will provide Rapid City with a comprehensive stormwater quality management plan that will insure future generations a healthy Rapid Creek.

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Introduction

Development within urban watersheds results in an impact on the physical, chemical, and biological integrity of the watershed. Urban development produces significant increases in stormwater runoff, which greatly impacts the quantity and quality of a receiving water (i.e. Rapid Creek). Current zoning and planning regulations have reduced these impacts by preserving sensitive areas such as wetlands and floodplains. However, developed areas continue to produce significant disturbances within urban watersheds due to the disturbance of soil and increased imperviousness. There have been efforts to control the impact of new development with the implementation of structures such as stormwater retention and detention facilities. These structures, designed mostly for flood control with little or no adaptation for storm water quality control, have been demonstrated to control certain types of pollution. However, they have been of limited value in comprehensively addressing ecosystem integrity (Department of Environmental Resources, 1997). Furthermore, retention and detention facilities have been found to be extremely unpopular within the neighborhoods for which they are planned. Local residents rightfully question whether traditional storm water management methods are the best answer.

Rapid Creek is one of the most important natural resources within Rapid City and the Black Hills. Above Baken Park, Rapid Creek is used for recreation, as a municipal water source, and for fish propagation. This stretch of Rapid Creek also contains one of the only Blue Ribbon trout fisheries in the state of South Dakota. Each watershed within Rapid City impacts the water quality of Rapid Creek. However, two urban watersheds, Wonderland and Arrowhead, empty into Rapid Creek within this important stretch of Rapid Creek directly below Canyon Lake (See Figure 1). These urban watersheds have highly developed areas within their boundaries and produce stormwater runoff that degrades the quality of Rapid Creek (Kenner, 1997). With the ever-growing popularity of Southwest Rapid City, each of these watersheds will continue to be developed. This development has the potential to create a water quality problem within Rapid Creek unless a stormwater management plan is enacted. As environmental regulations become enacted, Rapid City will be required to implement a stormwater management plan. If action is taken today it will cost taxpayers less than if implemented after the regulations are put in place.

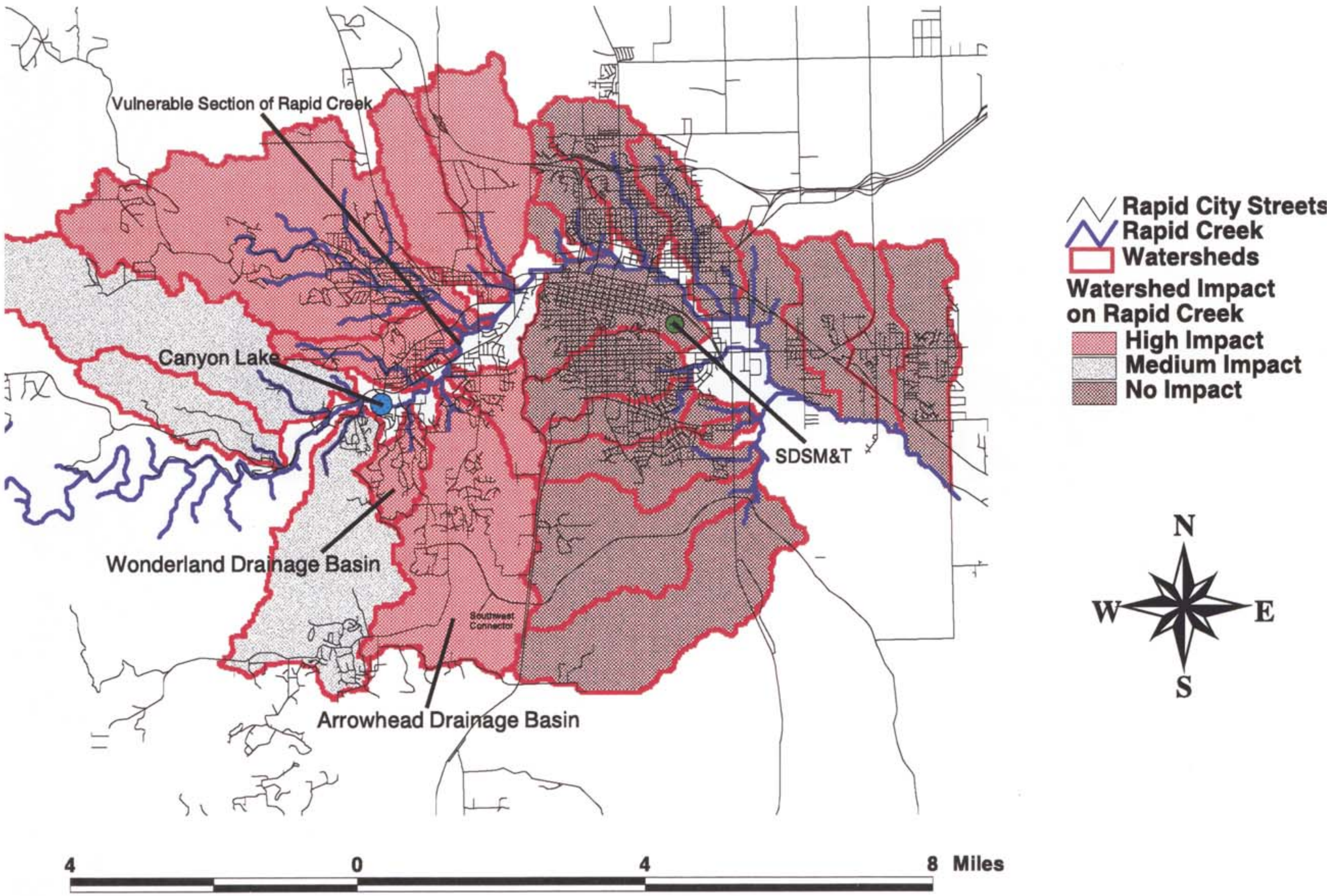

Figure 1. Watershed impact on Rapid Creek and site map.

This report examines one part of the solution for the current and potential water quality problems that exist in Rapid City. This potential solution is Low-Impact Development. The report will establish the need for Low-Impact Development, examine the techniques involved in Low-Impact Development stormwater quality control, and show that Low-Impact Development is a viable alternative to current stormwater control practices. Ultimately, the implementation of Low-Impact Development practices will allow for increased development within Wonderland and Arrowhead drainage basins and reduce the impact to ecosystems within each drainage basin and Rapid Creek.

This report is meant to be an introductory overview of the concepts involved with Low-Impact Development. Thus, many of the engineering considerations that are often seen in other technical reports are not found in the following pages. For the reader who is interested in the science and engineering behind Low-Impact Development, there are two technical documents that are referenced within this report. They are the Low-Impact Design Manual and Start at the Source, a design guidance manual for stormwater quality protection. Also, for the reader who is being introduced to the concepts of stormwater quality protection, there is a glossary in Appendix IV that provides definitions for many of the terms utilized within this report.

The Need for a Stormwater Quality Management Plan

There are certain primary reasons why the city if Rapid City needs a stormwater quality management plan. The first is the development that has occurred and will continue to occur in Southwest Rapid City. With the growing popularity and availability of land in this area of town, we will continue to see development within the Arrowhead and Wonderland drainage basins (See Figure 2). With this growth will come increased imperviousness (i.e. roads, housing, and compacted soils) and less natural conditions. This combination will increase the quantity of stormwater draining from these drainage basins. This will ultimately increase soil erosion and pollutant loading within the streams (Bay Area Stormwater Management Association, 1999). These two drainage basins empty into Rapid Creek where it is most susceptible. This could lead to the quality of Rapid Creek being degraded above

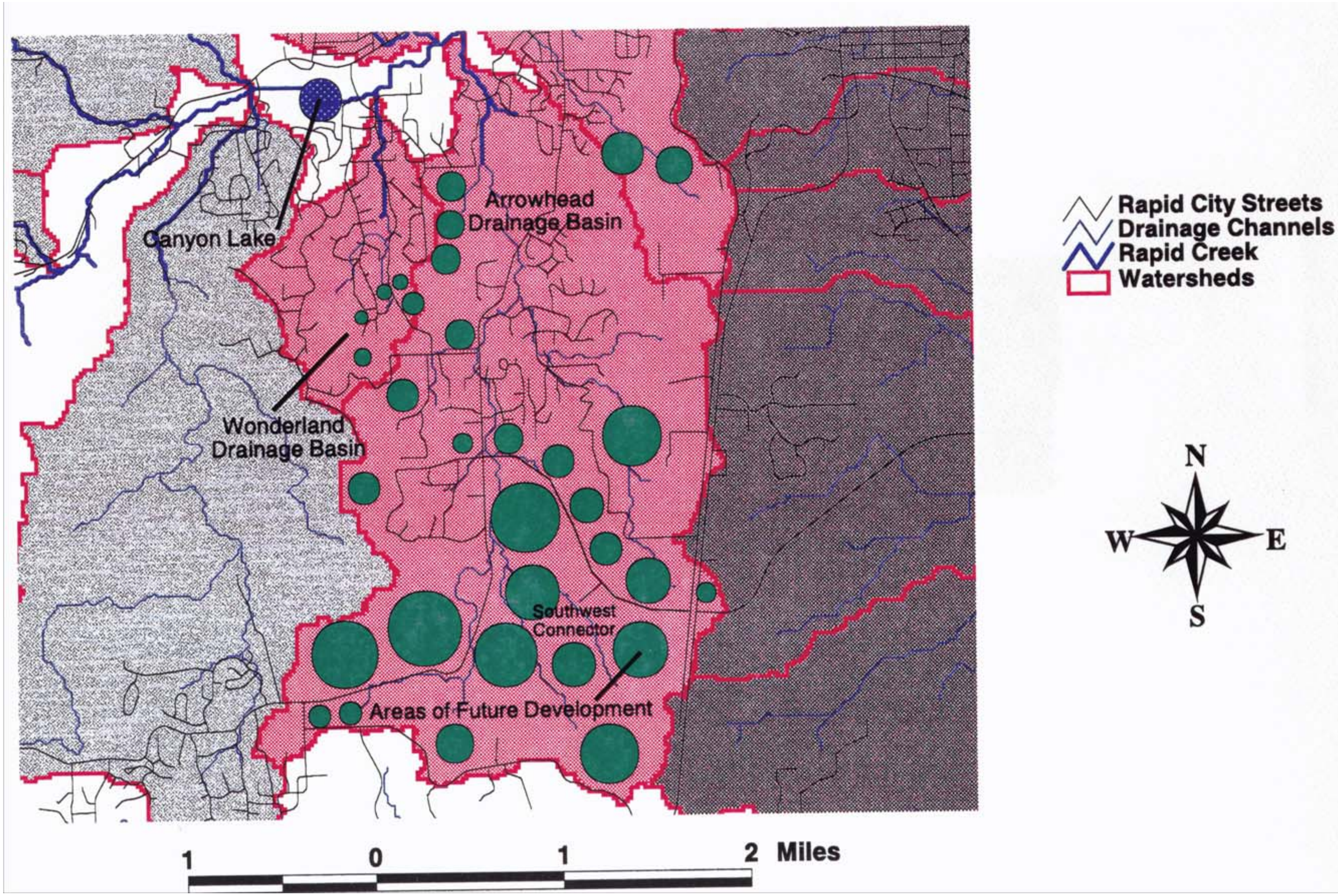

Figure 2. Future development within Wonderland and Arrowhead drainage basins.

Baken Park to the point where municipal water treatment becomes too expensive, recreational activities become unsafe, and fish reproduction declines or ceases (Kenner, 1997).

The second reason for the need for a stormwater quality management plan is the construction practices which developers are currently using within Rapid City (See Figure 3). There are many construction methods that are commonly used throughout the United States that lessen the impact development has on the stormwater quality within watersheds (Coffman, Personal Interview). There are still, however, instances within both Wonderland

Figure 3: This photo shows how a contractor has placed construction debris along a cutbank in the Wonderland drainage channel.

and Arrowhead drainage basins where developers and contractors have either ignored or have not been informed of the best stormwater management practices. Additional photographs of such construction activities and their effects can be seen in Appendix I.

Perhaps the most important reason why there is a need for Rapid City to implement a stormwater quality management plan is that the EPA will soon require the monitoring and treatment of stormwater runoff. The Clean Water Act of 1972, as amended in 1987, prohibits the discharge of pollutants into waters of the United States unless the discharge is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. An amendment, which will be enacted in late 1999, will require all municipalities over a population of 10,000 residents to "develop, implement, and enforce controls to reduce the discharge of pollutants from municipal storm sewers that receive discharges from areas of

Figure 4: Stormwater pollution from this site in the Arrowhead drainage basin could have been prevented with properly constructed silt fences and detention facilities.

new development and significant redevelopment… [including] after construction is completed." This 1999 amendment (Phase II of the Stormwater Regulation Amendment within the Clean Water Act) will become law in November 2002. Thus, the City of Rapid City will be required to implement a stormwater quality management plan to treat the stormwater produced from all drainage basins within the city in order to avoid EPA mandated fines. Unless a plan is implemented soon, Rapid City may be faced with an expensive dilemma once the EPA regulations are fully implemented (Bay Area Stormwater Management Association, 1999).

Low-Impact Development

Low-Impact Development (LID) is a comprehensive stormwater management strategy that has been developed over the past eight years in Prince George's County, Maryland and is now utilized throughout the United States, Japan, and Germany (Winogradoff, Personal Interview). It presents a new perspective on urban development by integrating site ecological and environmental requirements into all phases of urban planning and design. LID considers the implications of development on a broad scale ranging from the entire watershed to the individual residential lot. The Low-Impact Development approach balances urban development impacts and site design features while increasing lot yields and decreasing development costs thereby encouraging development and economic growth (Bay Area Stormwater Management Association, 1999).

A Low-Impact Development strategy treats stormwater at the source. This is done by implementing certain concepts within individual residential lots or entire residential developments. These concepts include:

- Reduced imperviousness
- On-lot storage and infiltration systems
- Functional landscaping
- Open drainage swales
- Flatter slopes
- Increased stormwater runoff travel time (lower velocities and less erosion)
- Enhanced infiltration and depression storage
- Minimized woodland disturbance
- Runoff water conservation and reuse

The utilization of these LID concepts will create a drainage system that, if properly applied and managed, will lessen stormwater flow quantities within a watershed. With lower stormwater flows, pollutant loading from lawn fertilizers and septic tanks will decrease. Channel erosion and sediment loading within the system will also be reduced (See Figure I-d in Appendix I). This will ultimately allow for increased development within a watershed without the cost of expensive and unpopular stormwater retention and detention facilities downstream (Department of Environmental Resources, 1997).

Objectives of Low-Impact Development

The objectives of Low-Impact Development include (1) restoring the site hydrologic conditions to mimic natural or pre-development conditions and (2) maintaining surface water and groundwater quality by minimizing the generation and off-site transport of pollutants.

Mimic Natural Hydrologic Conditions:

The development of a well-vegetated site, such as a forest or natural grassland, into a residential community disturbs the original site hydrologic response. Activities such as the clearing and eliminating of trees, piping and channelization of flow to minimize localized flooding, compacting of land surfaces, and the increase in impervious area all change the hydrologic conditions within a watershed. This disturbance results in higher peak stormwater flows for the 100-year storms as well as the smaller 2-year and 5-year storms that typically characterize and shape a drainage channel. These higher discharges are due to the loss of interception, infiltration, and depression storage that result from increased imperviousness and compaction within a watershed. An increase in the frequency and duration of higher stormwater flows is also due to the combined effects of runoff coefficients, flow routing, and transport patterns. Additionally, an increase is seen in the base flow due to increased imperviousness.

Each of these conditions adversely impacts the area downstream of the watershed. The downstream area can see an increase in flooding potential, accelerated erosion, streambank instability, and increased water temperature. Consequently, a significant degradation in receiving water biological integrity is seen. A low-impact development plan would lessen the effects which development has on the hydrologic conditions within a watershed (Department of Environmental Resources, 1997).

Maintain Surface Water and Groundwater Quality

The development of residential communities typically has an impact on the surface water and groundwater quality within a watershed. This is due to hydrologic changes that increase erosion processes and pollutant transport capacity. Development also impacts water quality by increasing the loading of several pollutants such as lawn and car care products. The impacts due to increased traffic such as road degradation also impact watersheds. Other non-typical pollutants that impact water quality include heavy metals, oil, grease, nutrients, pest control chemicals, and other toxic organics (Bay Area Stormwater Management Association, 1999). Increased bacteria and virus counts are also found in stormwater runoff. This is especially common in areas such as the Arrowhead drainage basin where there is a large concentration of individual septic tank systems (Kenner, 1997). A low-impact development strategy will reduce the impact of development on an ecosystem through the reduction of stormwater runoff from individual sites and entire developments. This reduction in stormwater runoff will lessen channel erosion, pollutant loading, and the need for expensive detention and retention structures downstream. The following section outlines the low-impact development strategies that can be utilized to obtain such a balanced ecosystem (American Society of Civil Engineers, 1998).

Low-Impact Development Strategies

The idea of low-impact development was born out of a bioretention project in Largo, Maryland. This project was aimed at protecting the water quality within a watershed by holding polluted stormwater on site with the use of a bioretention area. This concept later expanded into other low-impact development strategies such as swales, rain barrels, level spreaders, and vegetative strips to name just a few. Table 1 lists the low-impact development strategies that have been utilized to date and their function within the hydrologic and hydraulic system. Each of these strategies are explained in more detail following Table 1 and a schematic drawing of several Low-Impact Development designs and strategies can be seen in Appendices II and III.

Table 1. Low impact development strategies and their applications.

Low-Impact Best Management Practices	Runoff Reduction	Detention	Retention	Storm water Conveyance	Water Quality Treatment
Bioretention	√		√		√
Infiltration Trench	√		√		√
Dry Wells	√		√		
Roof-Top Storage	√	√			
Vegetative Filter Strips	√			√	√
Level Spreader	√	√		√	
Rain barrels	√	√	√		
Cisterns	√		√		
Reduced Culvert Size	√	√		√	√
Swale	√	√		√	√
Infiltration Swale	√	√	√	√	√
Swale with Weir Control	√	√		√	√
Infiltration Swale with Weir Control	√	√	√	√	√
Minimize Impervious Area	√				√
Strategic Clearing and Grading	√				√
Vegetated Buffers	√				√
Engineered Landscaping	√				√
Curb and Gutter Elimination	√				√

Bioretention: A stormwater Best Management Practice (BMP) which is designed to mimic forested systems that naturally control hydrology through infiltration and evapotranspiration. Very well suited for residential and commercial areas where additional landscaping can provide improved aesthetics (A bioretention schematic design can be seen in Appendix II).

Infiltration Trench: Very similar in design and function to the bioretention area except that it is less aesthetic.

Dry Wells: Small excavated trenches backfilled with stone. Dry wells function as infiltration systems used to control runoff from building rooftops (A dry well schematic design can be seen in Appendix II).

Roof-Top Storage: The idea of storing roof-top stormwater with the use of larger storm gutters which utilize weir control to reduce and regulate the flow.

Vegetative Filter Strips: Bands of close-growing vegetation, usually grass, planted between pollutant source areas and a downstream receiving waterbody. The strips can also be used as outlet or pretreatment devices for other stormwater control practices.

Level Spreader: An outlet which is designed to convert concentrated runoff to sheetflow. This dispersion of flow reduces the erosion potential of stormwater runoff (A level spreader schematic design can be seen in Appendix II).

Rain Barrels: Low-cost, effective, and easily maintainable retention devices applicable to both residential and commercial low-impact development sites. Rain barrels allow for a predetermined volume of roof stormwater runoff to be retained, thereby decreasing the site-runoff. This volume can then be used at a later time for lawn and garden watering (A rain barrel schematic can be seen in Appendix II).

Cisterns: Stormwater runoff cisterns are roof water management structures that provide above ground and underground retention storage volume. On-site storage and reuse of the stormwater provides an opportunity for water conservation during periodic dry periods and the potential reduction of water utility costs for homeowners (A cistern schematic design can be seen in Appendix II).

Reduced Culvert Size: The reduction of culvert size will reduce and slow the flow of stormwater through a drainage system. This will allow for increased infiltration.

Swale: Utilized along roadways, swales are earthen channels covered with a dense growth of hardy grass, such as Tall Fescue. Swales are better suited for stormwater management than typical channels because they do not erode, thereby reducing the sediment load and stormwater velocity. Swales are also good substitutes for traditional curb and gutter methods. By utilizing swales, stormwater that is produced on streets can infiltrate rather than being piped downstream. (A schematic swale design can be seen in Appendix II).

Infiltration Swale: An infiltration swale works in the same way as a grassy swale except that its slope is lessened. This allows for more ponding and infiltration.

Swale with Weir Control: Weir control within a swale provides increased ponding and infiltration. The weir control outlet also decreases and regulates the flow downstream (A weir control outlet schematic can be seen in Appendix II).

Minimize Impervious Area: The reduction of imperviousness within a watershed is the most effective way to reduce stormwater runoff. Any reduction in impervious areas, such as roads, sidewalks, and driveways, will ultimately reduce the runoff from a development and thus reduce erosion and pollutant loading downstream. The key to minimizing impervious area is to disconnect the impervious areas. This, in turn, directs stormwater towards pervious areas. Traditional stormwater management methods call for stormwater to be drained through a gutter system, channeled down a concrete driveway, and directed into a stormwater pipe where it is then drained into a receiving water body. A reduction in the connected impervious area will allow for the hydrologic response to be lessened while still providing basic amenities such as driveways and sidewalks (Different strategies for reducing the effective impervious area within a development can be seen in Appendices II and III).

Strategic Clearing and Grading: Another very effective method of reducing stormwater quantity and erosion impacts on downstream receiving waters. Strategies include minimizing the clearing of forested areas and grading the area in such a way as to flatten slopes, increase the flow path length, maximize sheet flow, and increasing surface roughness.

Vegetated Buffers: Strips of vegetation, either natural or planted, which are utilized around sensitive areas such as water bodies or wetlands. The buffers reduce stormwater runoff impacts by trapping sediment and sediment-bound pollutants, encouraging infiltration, and dispersing stormwater flows.

Engineered Landscaping: A method of mitigating the hydrologic impacts of clearing and grading. In cases when the majority of a site must be cleared, a carefully designed landscaping plan can be implemented to return the site to natural conditions. Heavily revegetated areas can improve sediment removal, infiltration, and community aesthetics.

Curb and Gutter Elimination: Addresses both quantity and quality aspects of stormwater management. The idea of eliminating or reducing the use of curb and gutter allows the site imperviousness to be disconnected. This, in turn, causes the stormwater, which would normally runoff directly into a storm drain, to be dispersed to vegetated buffers, bioretention areas, or roadside swales (Department of Environmental Resources, 1997).

Economic Benefits Associated with Low-Impact Development

A watershed management plan that integrates stormwater quality, as well as quantity, will save money downstream. There will be less of a need for costly and unpopular stormwater detention and retention facilities within individual watersheds. The water treatment processes downstream will also become less expensive because less treatment will be needed. Additionally, invaluable fish propagation and recreational activities will continue to be possible. However, the economic benefits of Low-Impact Development do not stop here. The developer, real estate agent, and homeowner will see economic benefit in cost savings associated with the construction and maintenance of individual lots and developments. A Low-Impact Development stormwater management plan will not increase the cost of development because it demands only that developers and contractors change their methods of producing the same property. With Low-Impact Development there can be less earthwork, less infrastructure, and the development will be more aesthetically pleasing to the homeowners. Therefore, as consumers become more aware of the impact which development has on our environment, the use of Low-Impact Development will likely increase the value of the property (Winogradoff, Personal Interview). This has already been observed in the states of Virginia, Illinois, Kansas, and Colorado. It has been shown in these states that residential lots, which have been planned with stormwater runoff control in mind, command a 5% to %15 premium over comparable lots that had not utilized stormwater control measures (Bay Area Stormwater Management Association, 1999). Below is a list of the cost saving measures that are associated with a Low-Impact Development watershed management plan.

- Less clearing of trees
- Less earth work
- Less stormwater piping
- Fewer drainage control structures
- Minimum use of roadside curb and gutter
- Less road pavement
- Fewer sidewalks (less width)
- Lower wetland, tree, and stream mitigation costs
- Developer savings through less infrastructure costs (including the lack of necessity for a centralized detention facility), increased marketability of the development to an ever-growing environmentally conscious buyer, and potentially greater lot yields due to the less infrastructure such as detention ponds and wider roads.
- In general, the development will look more aesthetically pleasing, thus creating a more marketable development (Coffman, n.d.).

Implementation of a Low-Impact Development Plan

Rapid City must implement a stormwater quality management program before November

2002. Otherwise, the city will face EPA mandated fines. Thus, it is in the city's best interest to develop a stormwater quality management plan in the near future. This plan should incorporate the use of Low-Impact Development. Low-Impact Development stormwater quality management strategies have been implemented in other communities throughout the United States and Europe (Winogradoff, Personal Interview). The Low-Impact Development theory has become widely used because it treats stormwater at the source. It allows property to be developed without a tremendous increase in stormwater quantity. This provides cost savings for the developer, homeowner, local government, and every tax-paying citizen by lessening the need for expensive treatment facilities at the outlet of each watershed (Bay Area Stormwater Management Association, 1999).

In other communities throughout the United States, Low-Impact Development stormwater quality management plans have been implemented by the cooperation of the local government and local developers. This has been accomplished by the developer volunteering to utilize Low-Impact Development concepts throughout a proposed development. In return, the local government allows the developer to utilize the Low-Impact Development concepts, even though they may not conform to local construction codes regarding curb and gutter and street widths (Winogradoff, Personal Interview). The implementation process of Low-Impact Development within Rapid City can also include the South Dakota School of Mines and Technology, which will assist any developer with the design, construction, and monitoring of a Low-Impact Development stormwater quality management plan. With the cooperation of local developers, the City of Rapid City, and the South Dakota School of Mines and Technology, a stormwater quality management plan that utilizes both Low-Impact Development and traditional stormwater management concepts can be enacted before the November 2002 deadline.

Conclusion

Rapid City is very fortunate in that we have a tremendous natural resource in Rapid Creek. The stream provides the city with a water source, recreational activities, fish propagation, and quality aesthetics that we have all grown to love. However, Rapid City is now at a crossroads. Southwest Rapid City has seen a tremendous increase in development the past ten years and will undoubtedly continue to see increased development. With this increase in development, there comes the potential for the health of Rapid Creek to become degraded. The same progression has been witnessed time after time in communities all across the United States. In each instance, the water quality within the receiving water body has been degraded to the point of no return because of stormwater pollution. The communities now live with water sources that are unusable. This does not have to be the fate of Rapid City. We now have the knowledge to maintain the water quality within our watersheds through ideas such as Low-Impact Development and other traditional practices such as detention and retention facilities. We also have the opportunity to utilize these practices before the watersheds are completely developed. It is now only a matter of implementing the knowledge we have, so that future generations in Rapid City will be able to have the same quality of life that we have been fortunate enough to experience.

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Winogradoff, Derek. Personal Interview. August 19, 1999.

Appendix I

(Stormwater Pollution Photographs)

Figure 1: This photograph shows a poorly constructed silt fence with an “earthen dam” placed behind it to control the stormwater runoff.

Figure 2: The polluted stormwater runoff in this picture originated on the property seen in the photograph above. Better stormwater pollution control practices on this property could have prevented this sediment pollution.

Figure 3: This photograph was taken downstream of the property on the previous page within the Arrowhead drainage basin. Stormwater pollution such as this will continue within the drainage basin unless a stormwater management plan is developed and enforced.

Figure 4: Recent development above this section of the Wonderland drainage channel has increased the stormwater runoff within the basin. This increase in runoff has eroded the channel significantly the past two years. This photo shows how the channel has been eroded down to the bedrock.

Figure 5: Recent construction within the Wonderland drainage basin will not only increase the flows within the channel due to an increase in imperviousness, but, as can be seen in this photograph, poor construction practices have also led to debris being placed directly into the channel. This construction debris will ultimately degrade the water quality within Wonderland drainage basin and Rapid Creek.

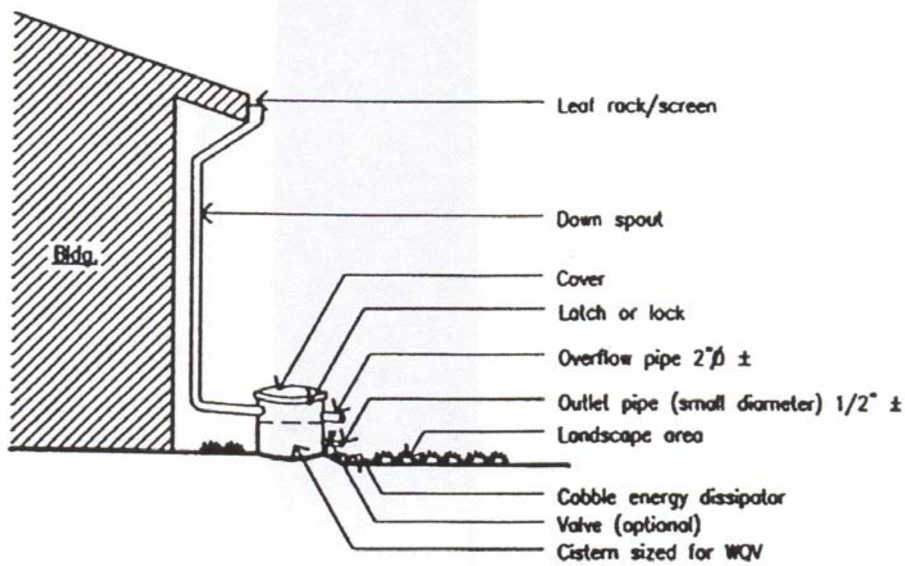
Figure 6: This photograph was taken upstream of the photograph above. It proves that poor construction practices are happening too often. Hopefully, once developers, contractors, and the general public are informed of the proper ways to keep our waters healthy, instances like these will become a thing of the past.

Appendix II

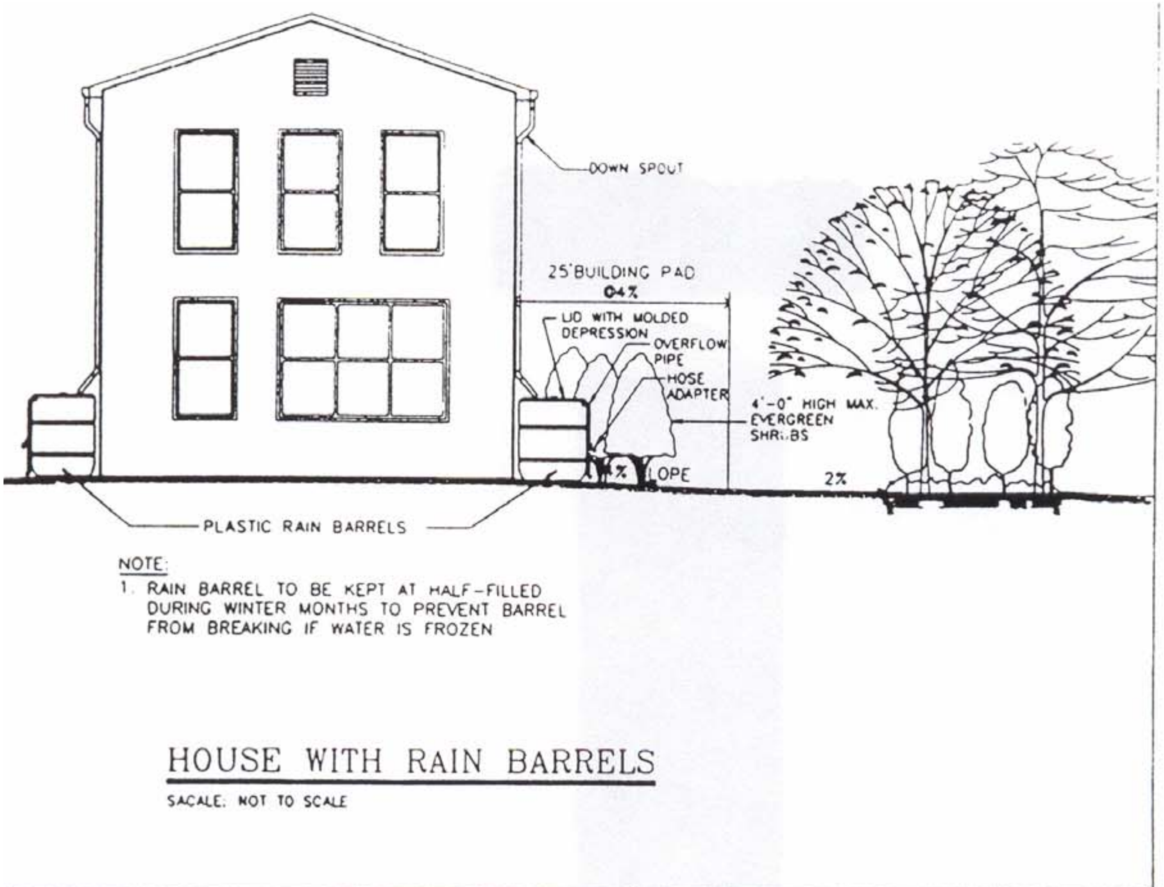
(Detailed Low-Impact Development Schematic Designs)

The following schematic designs were provided by the Low-Impact Design Manual (Department of Environmental Resources, 1997) and Start at the Source (Bay Area Stormwater Management Association, 1999).

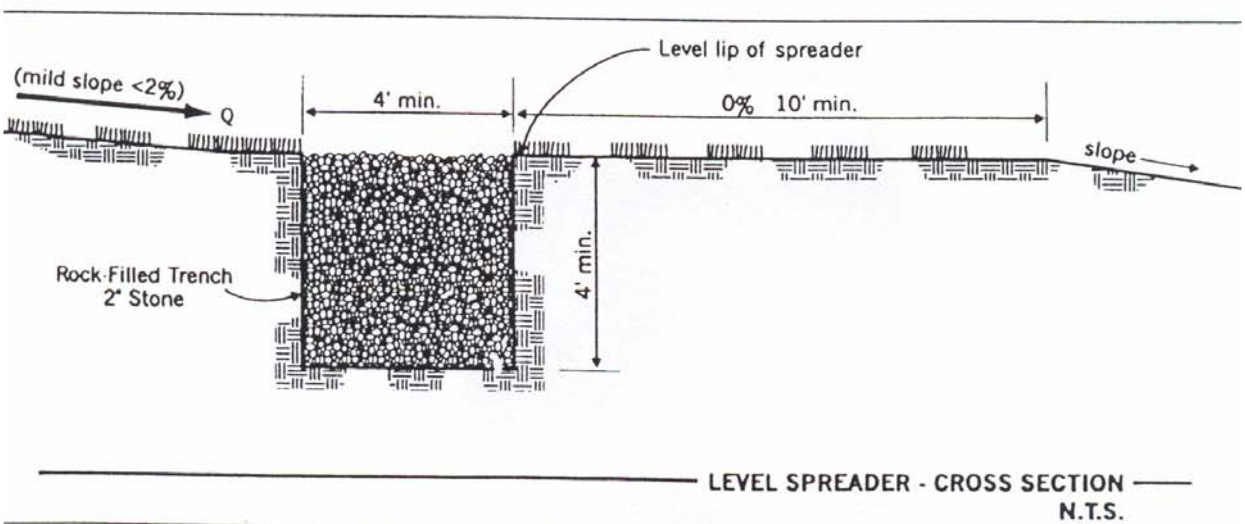
Cistern



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

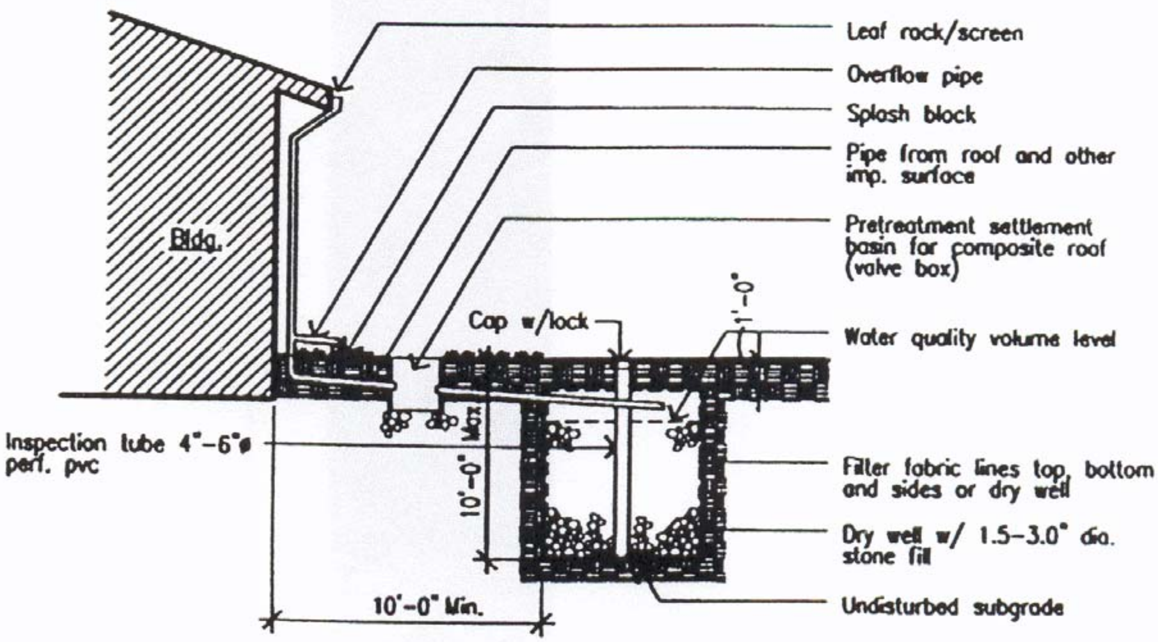


Typical Rain Barrel



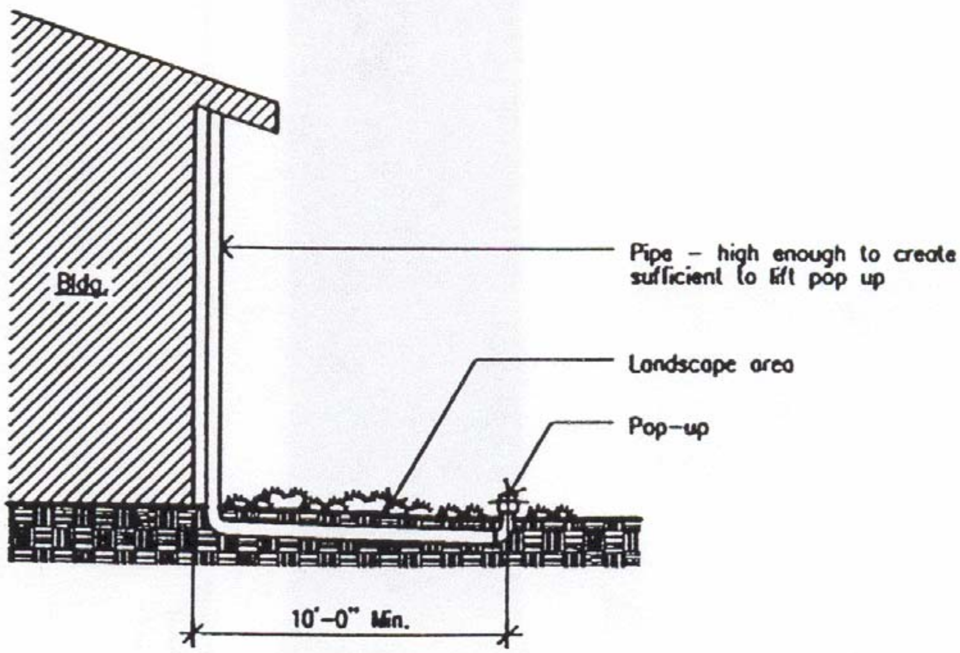
Typical Rock Trench Level Spreader

Dry-well



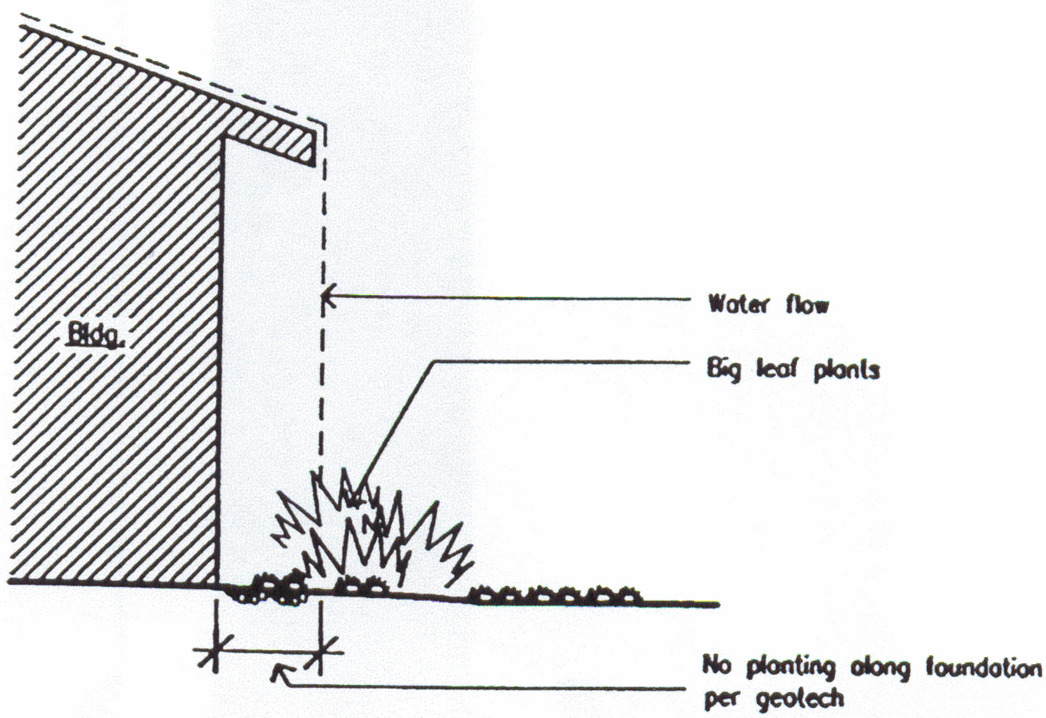
materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Pop-up drainage emitter



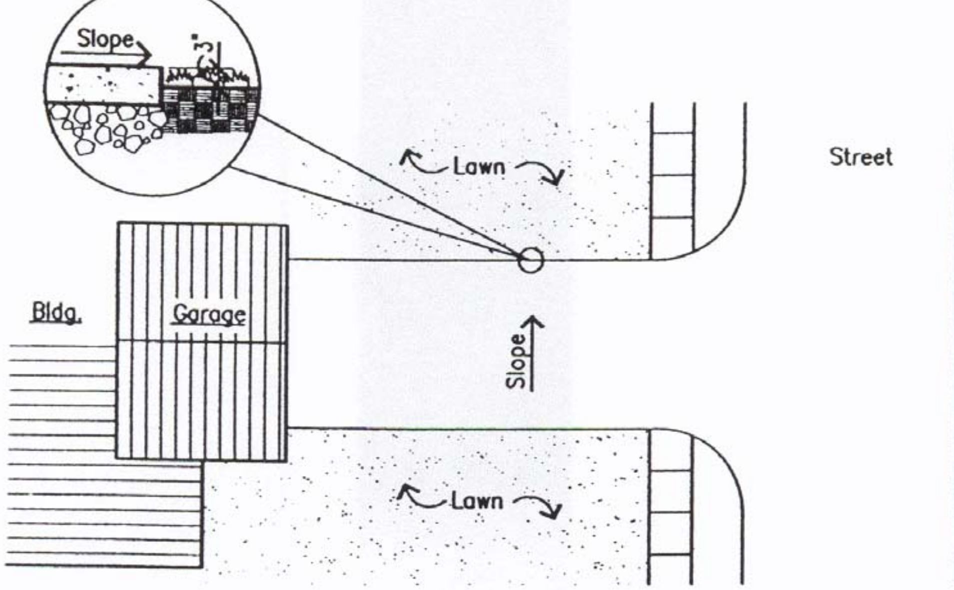
...s, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Foundation planting



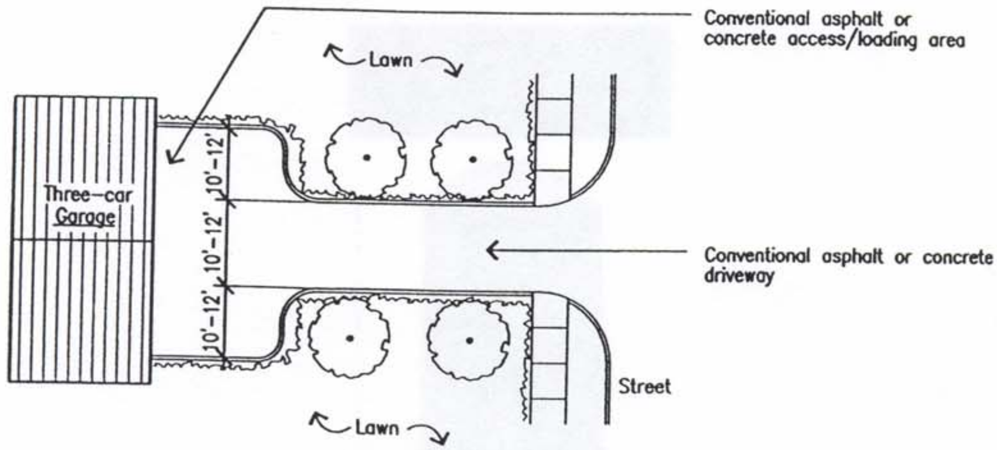
hown are typical. Modifications may be required for proper application, consult qualified professional.

Not-directly connected impervious driveway



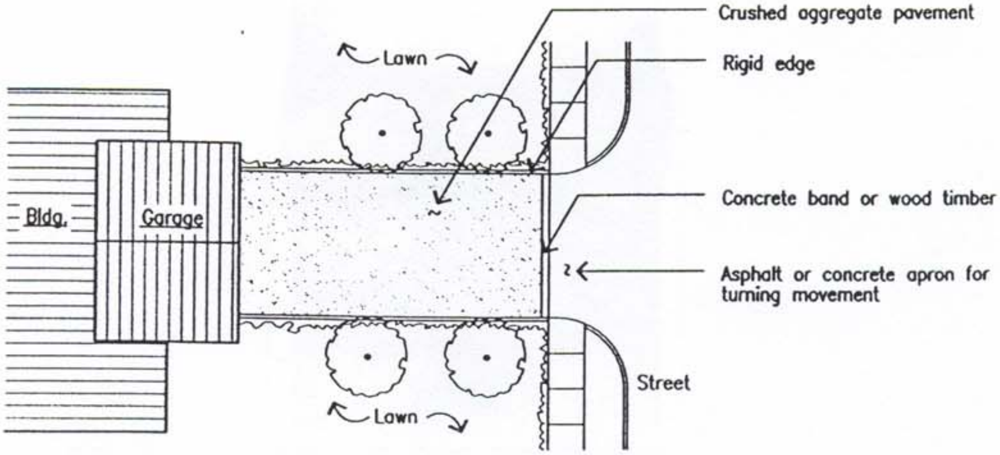
naterials shown are typical. Modifications may be required for proper application, consult qualified professional.

Flared driveways



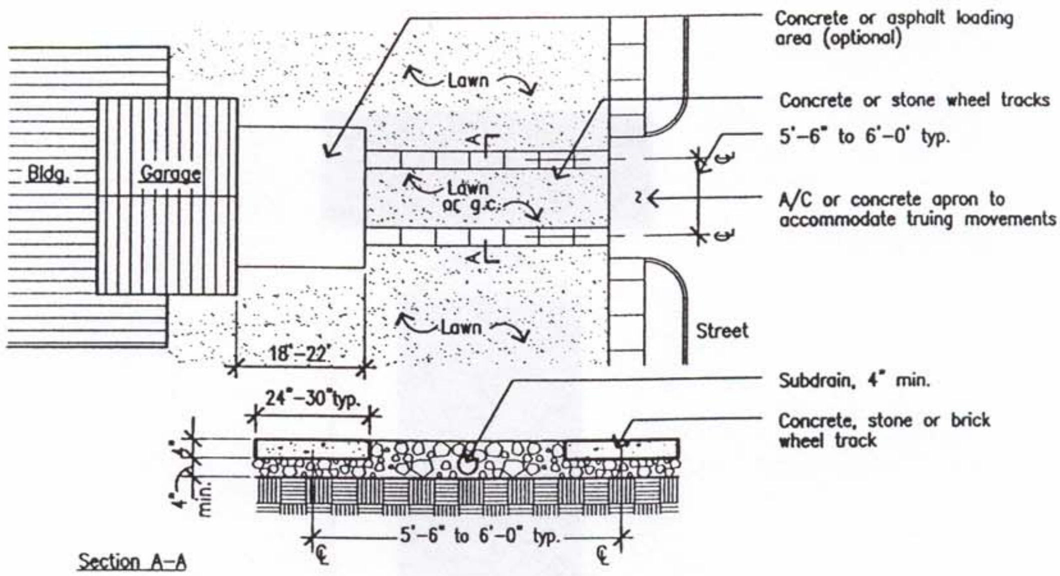
Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Crushed aggregate driveway



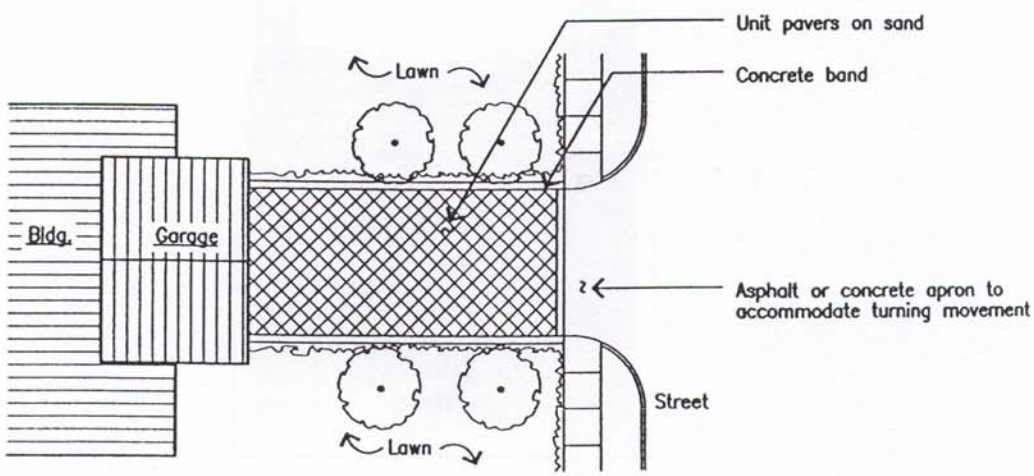
Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Paving only under wheels



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Unit pavers on sand driveway



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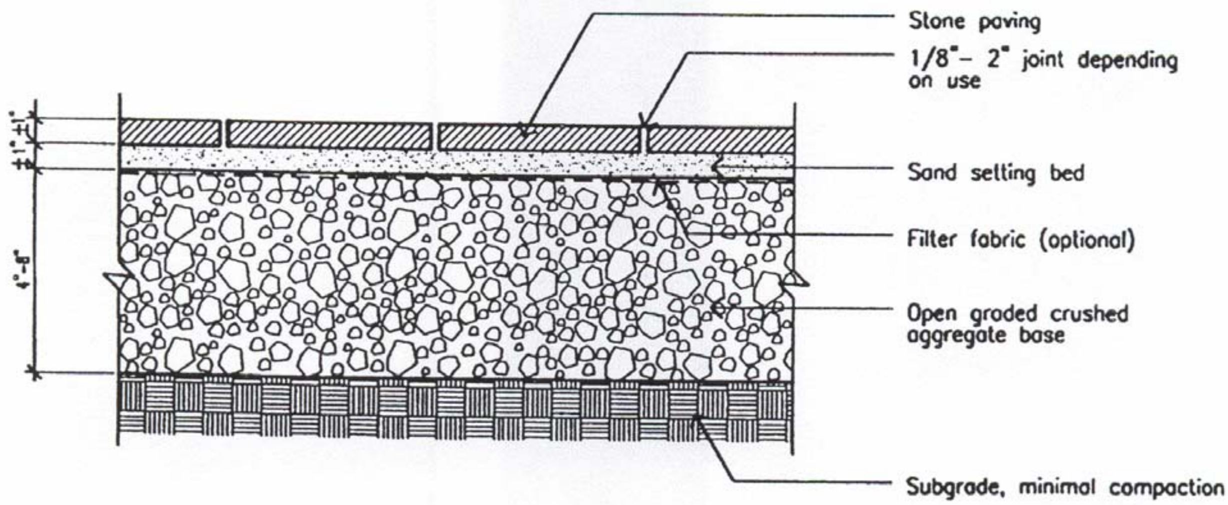
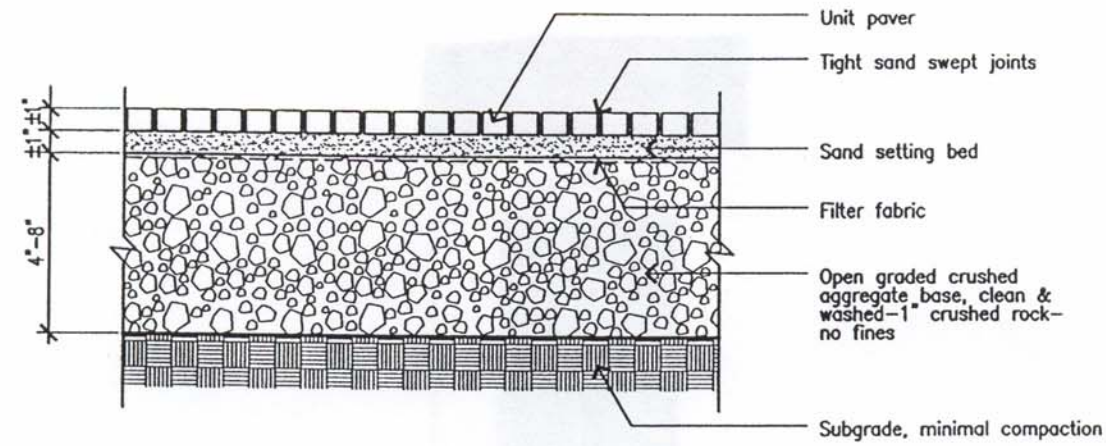
Natural stone



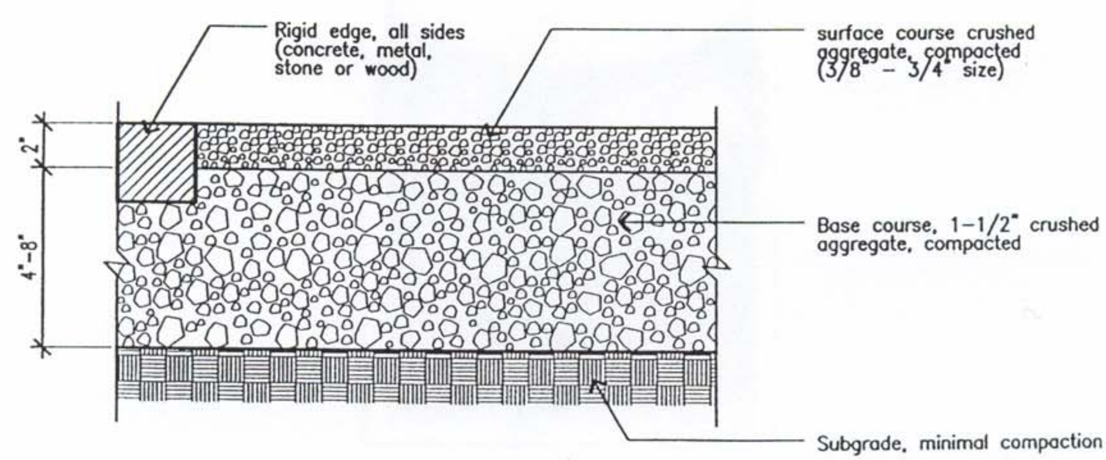
dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Unit pavers on sand



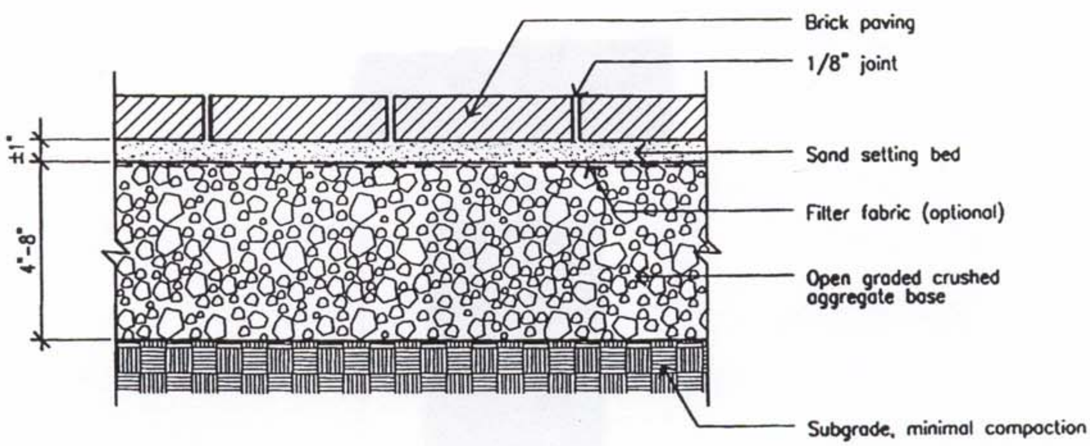
Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Crushed aggregate



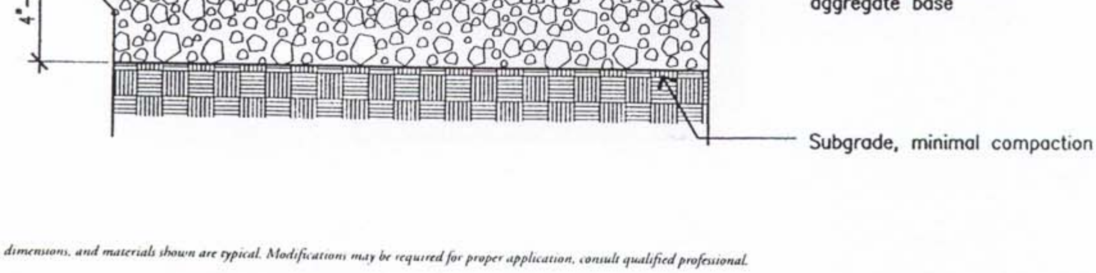
Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Brick



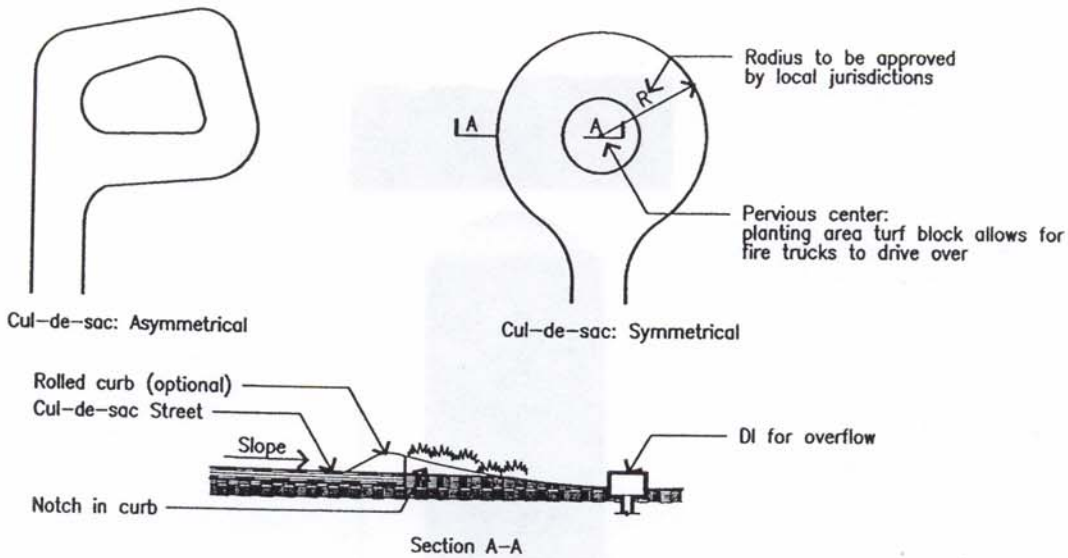
Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Turf block



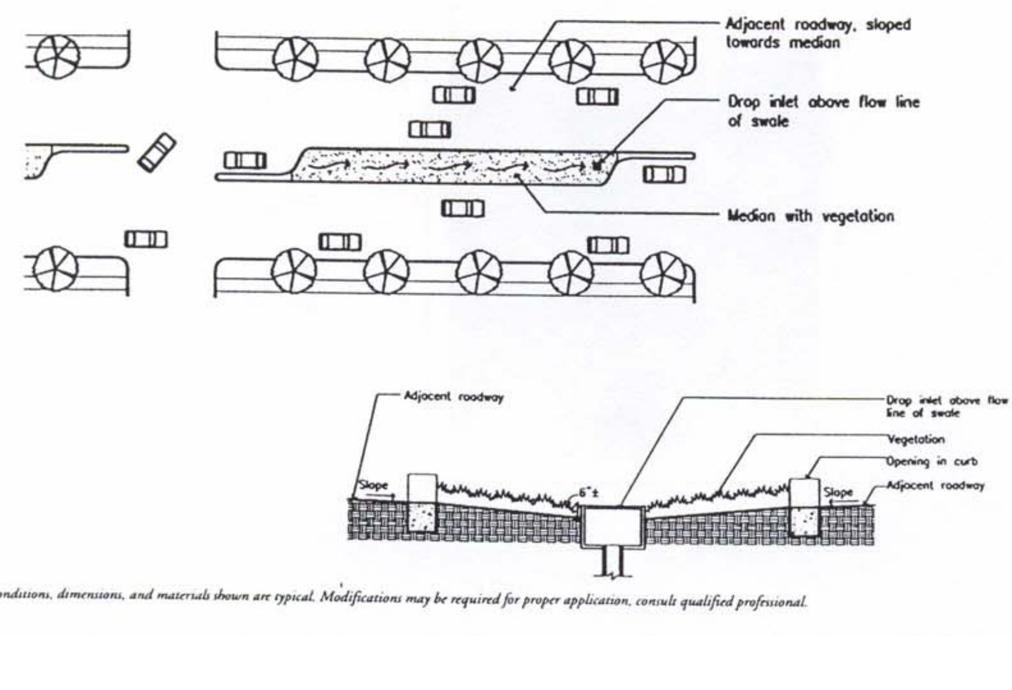
nditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Cul-de-sac



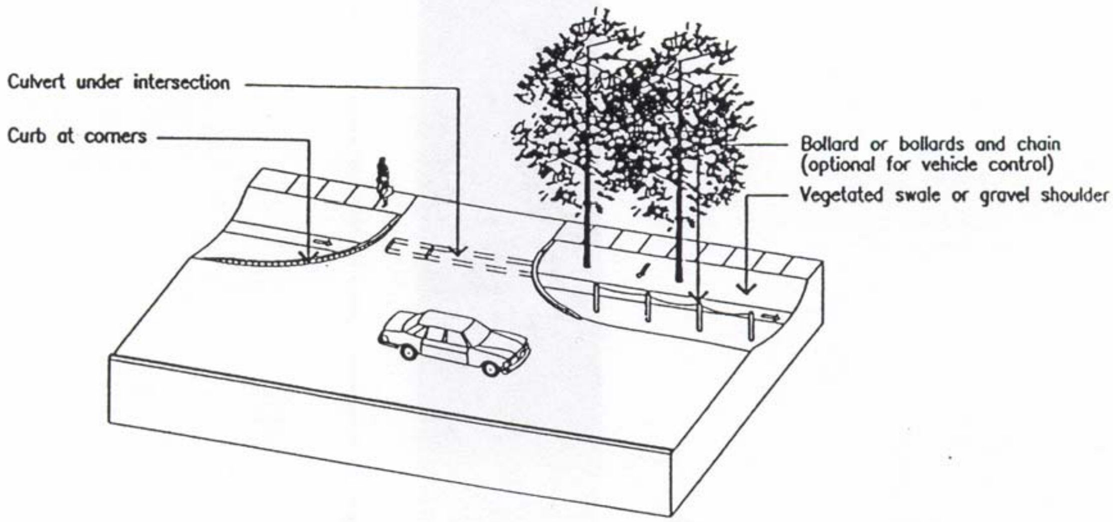
Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Concave median

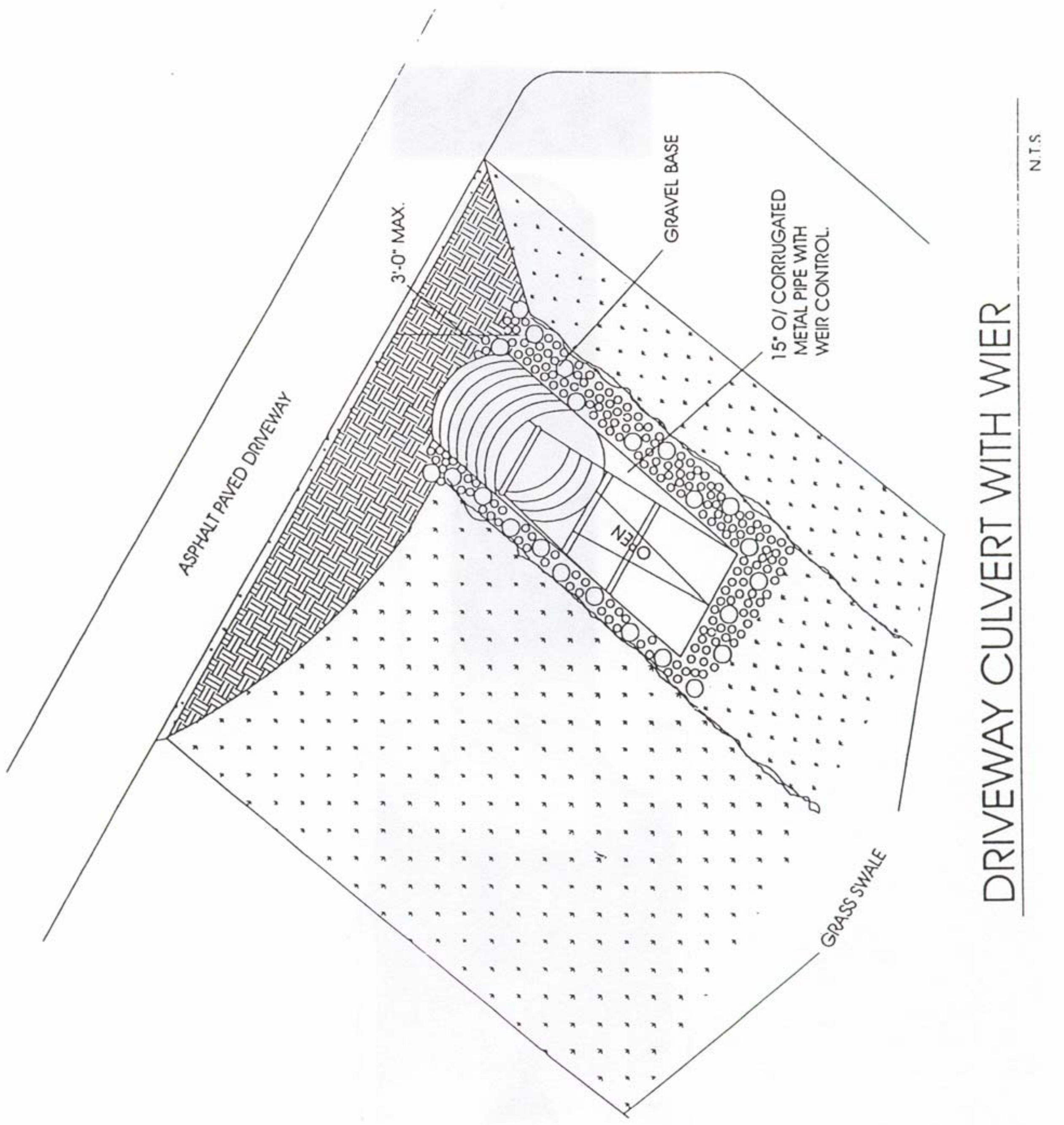


Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

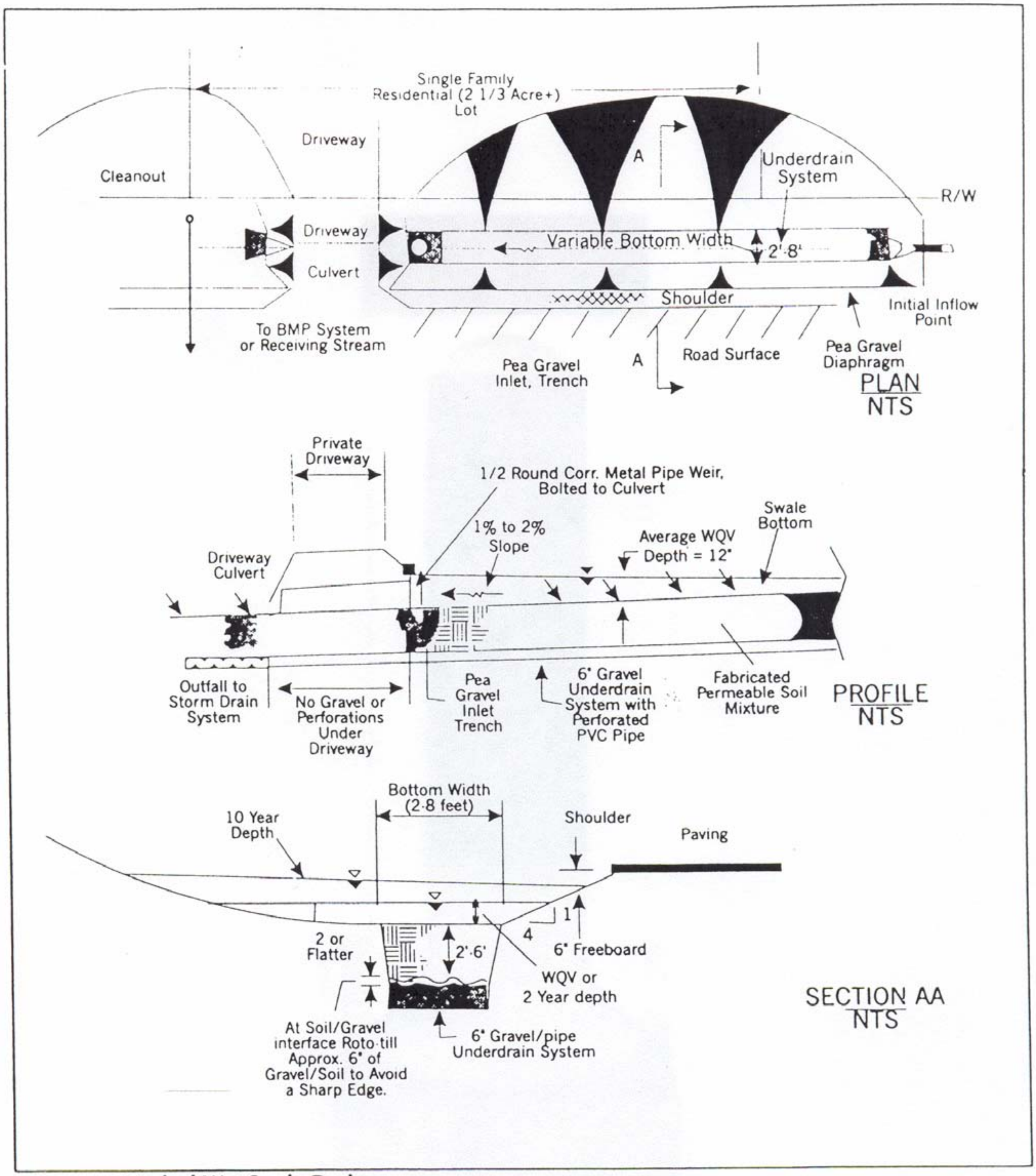
Rural swale system



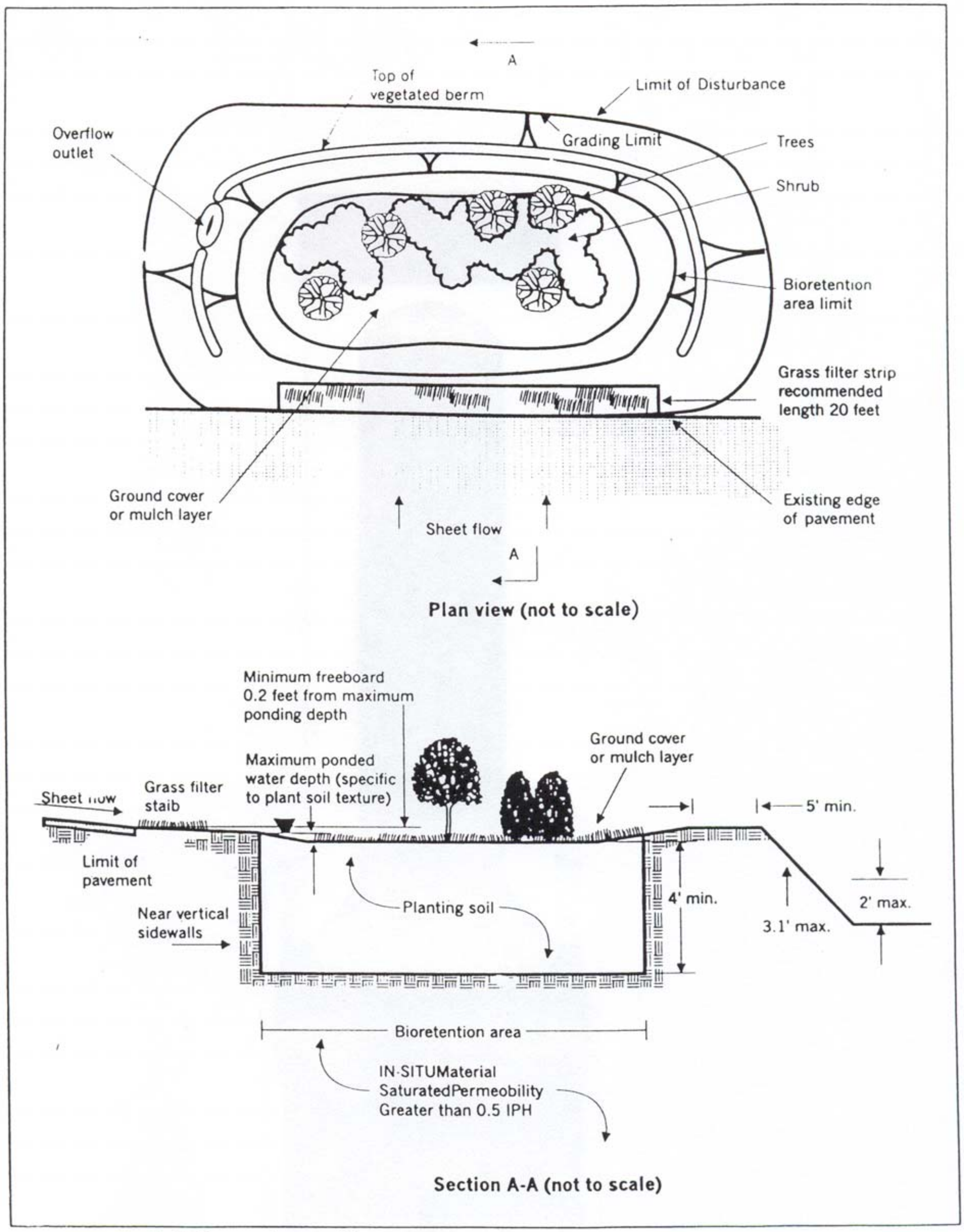
Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.



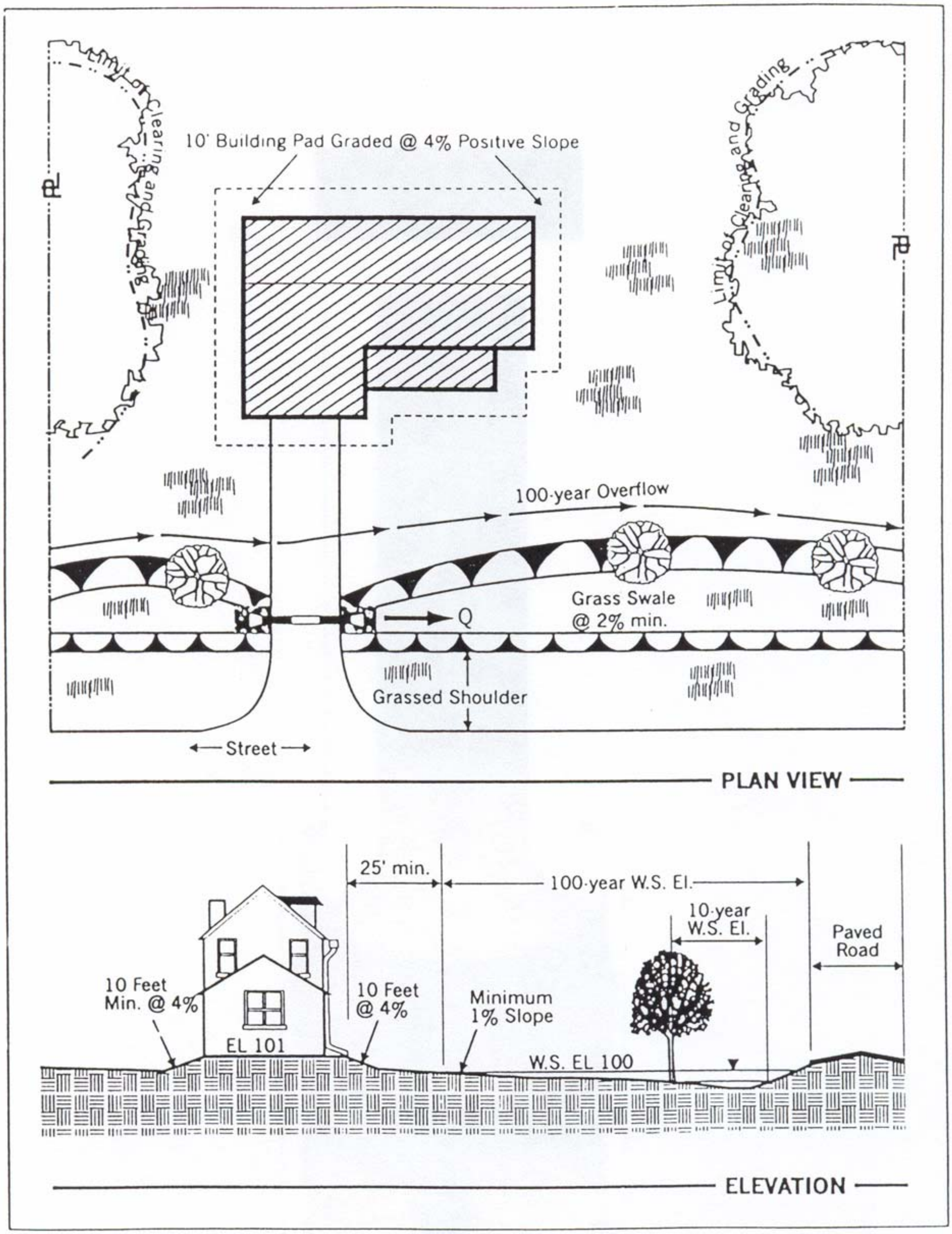
ASPHALT PAVED DRIVEWAY
3'-0" MAX.
GRAVEL BASE
15" O/ CORRUGATED
METAL PIPE WITH
WEIR CONTROL.
OPEN
GRASS SWALE
DRIVEWAY CULVERT WITH WIER
N.T.S.



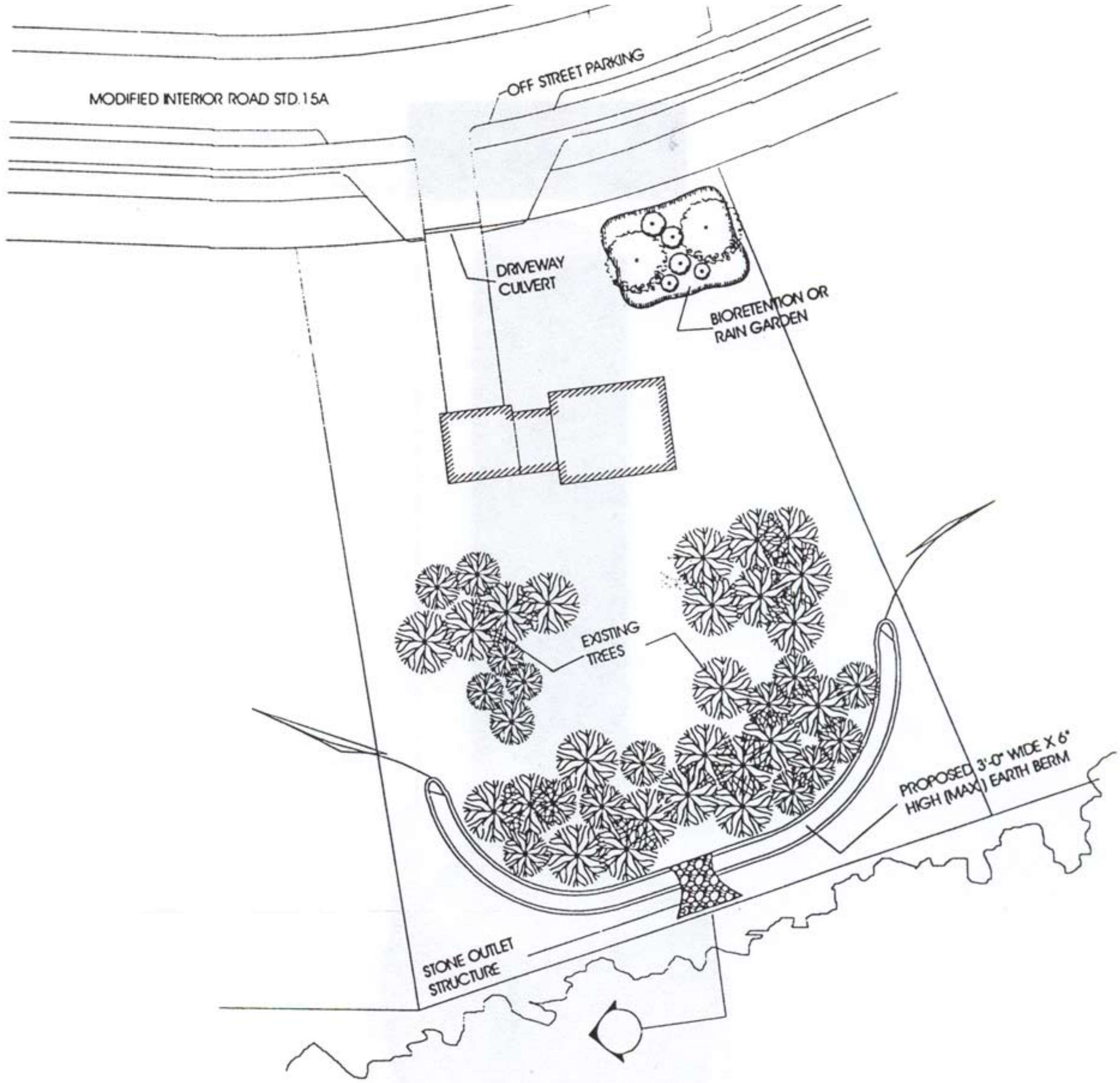
Typical Wet Swale Design



Typical Bioretention Facility



Low-Impact Development Minimum Lot Grading and 100-yr Buffer Requirements



LOT PLAN SHOWING EARTH BERM AROUND EXISTING TREES

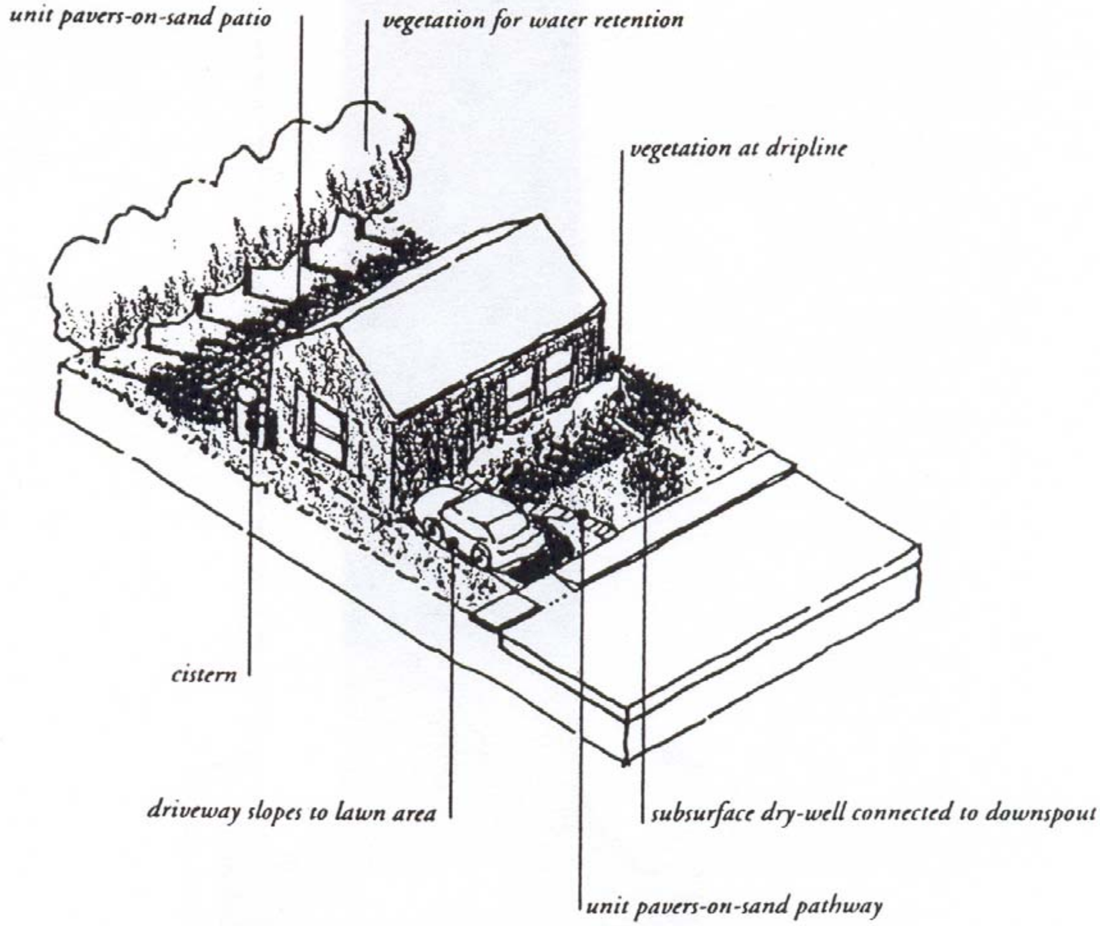
NOT TO SACALE

Appendix III

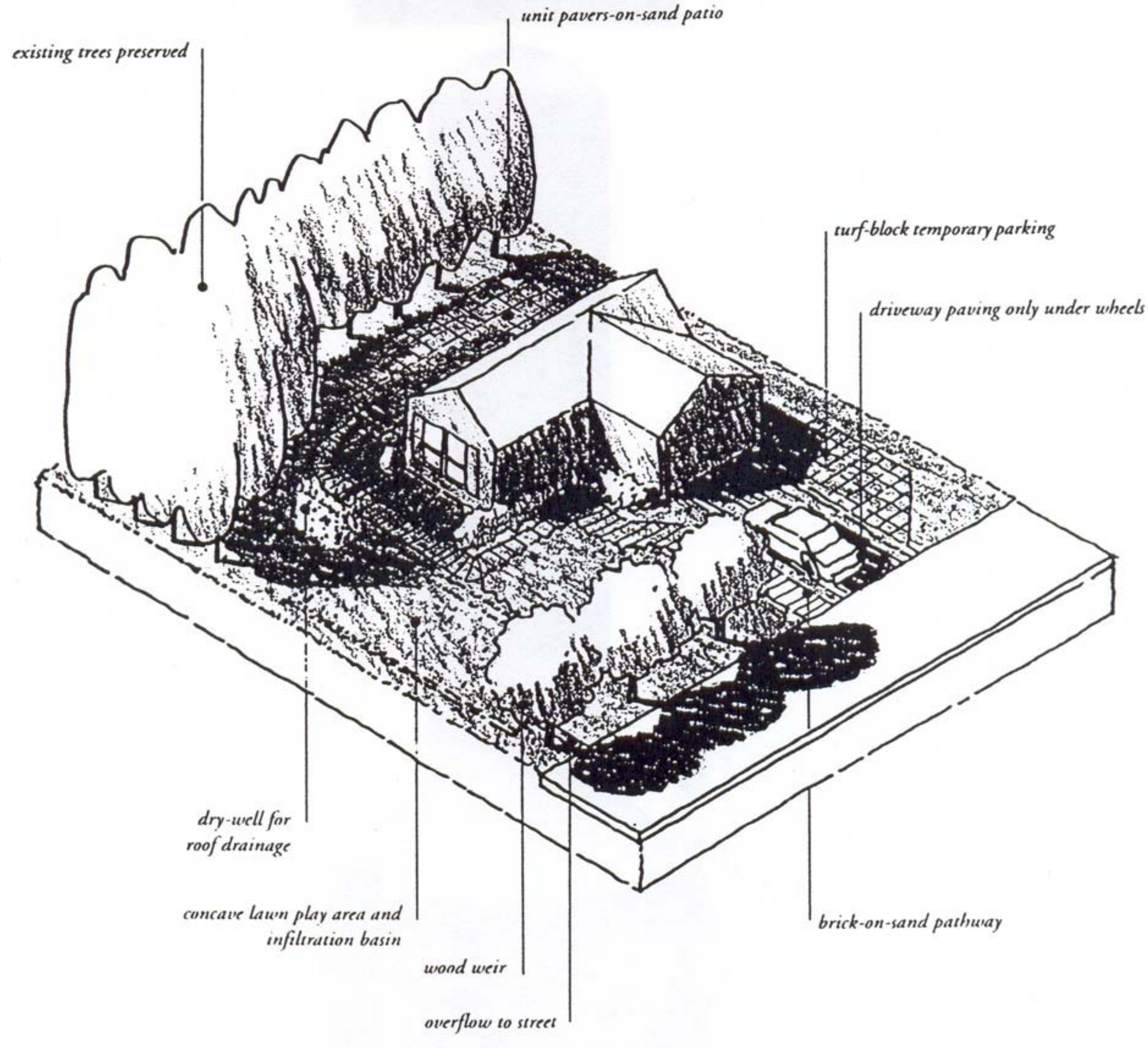
(Conceptual Low-Impact Development Strategies)

The following conceptual strategies were provided by Start at the Source, a design guidance manual for stormwater quality protection (Bay Area Stormwater Management Association, 1999).

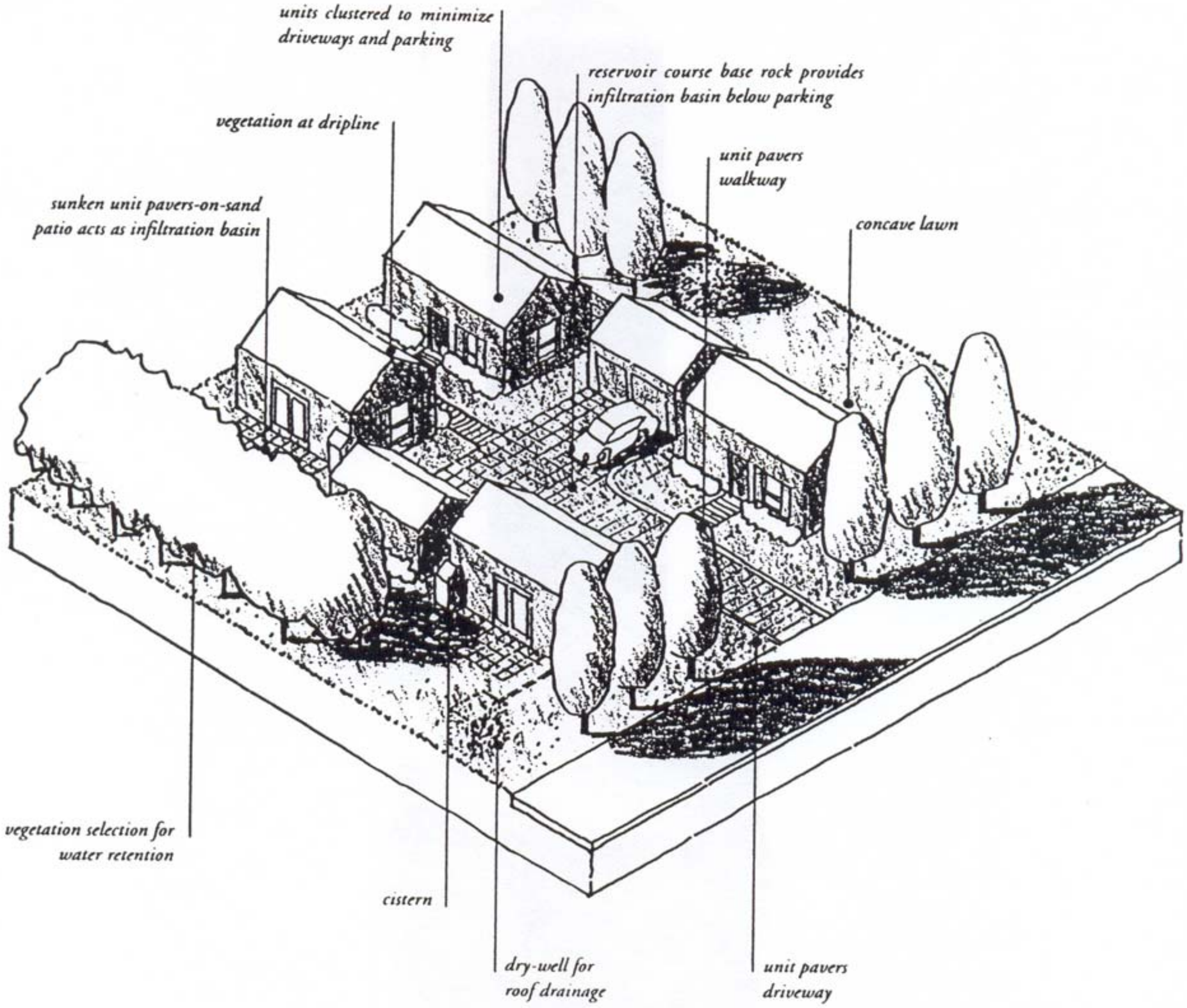
Small single lot



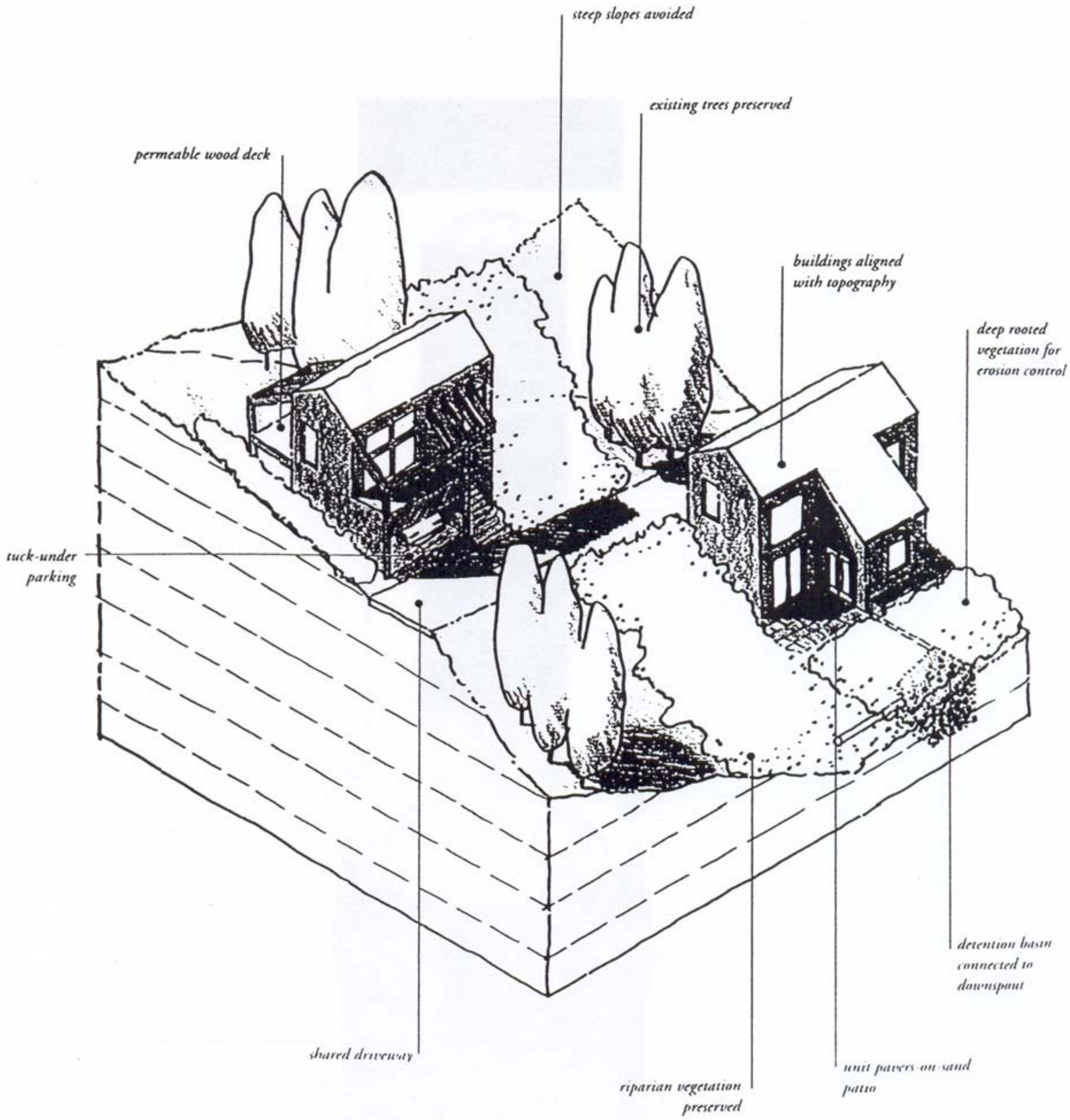
Large single lot



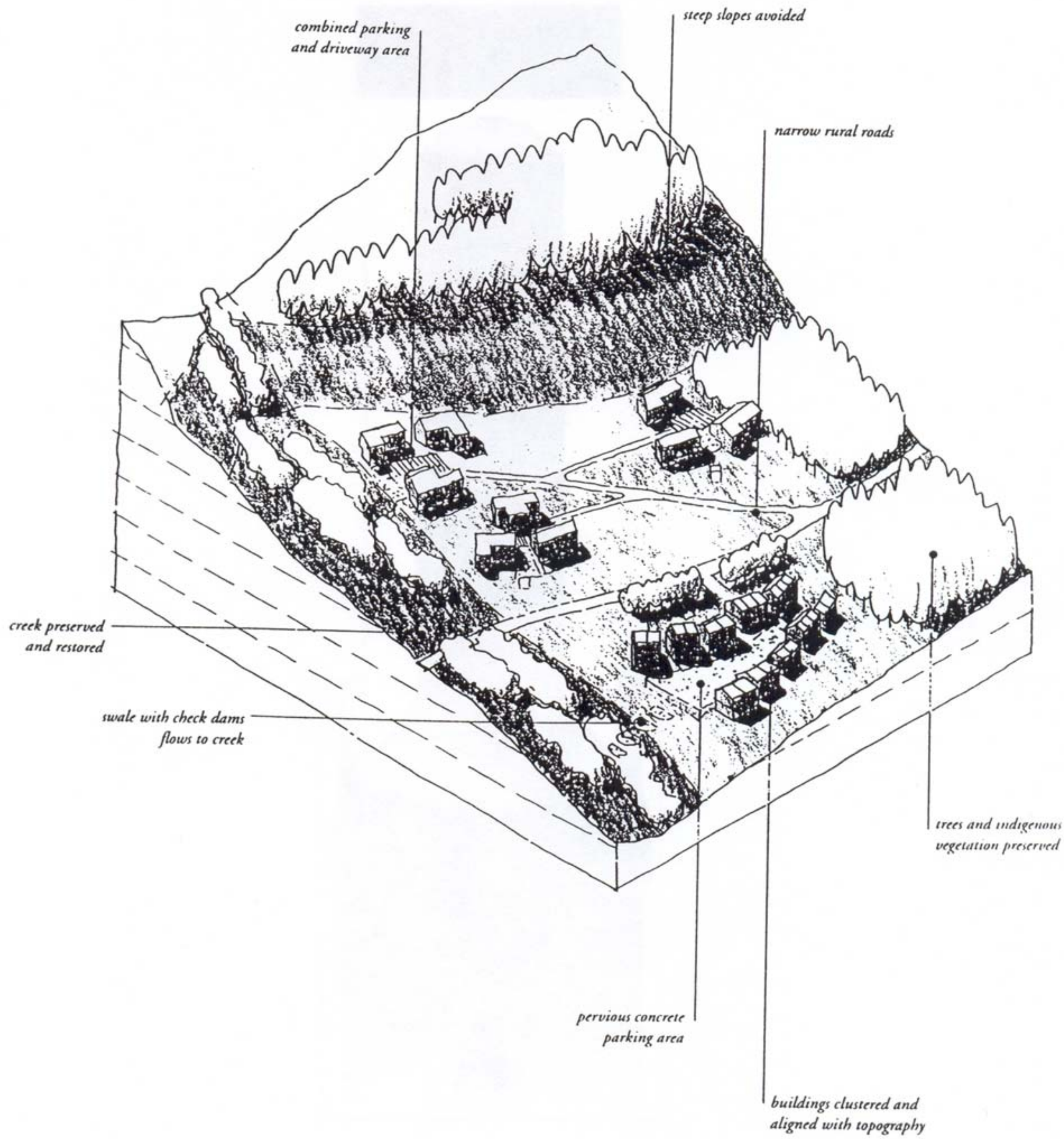
High density multi-family site



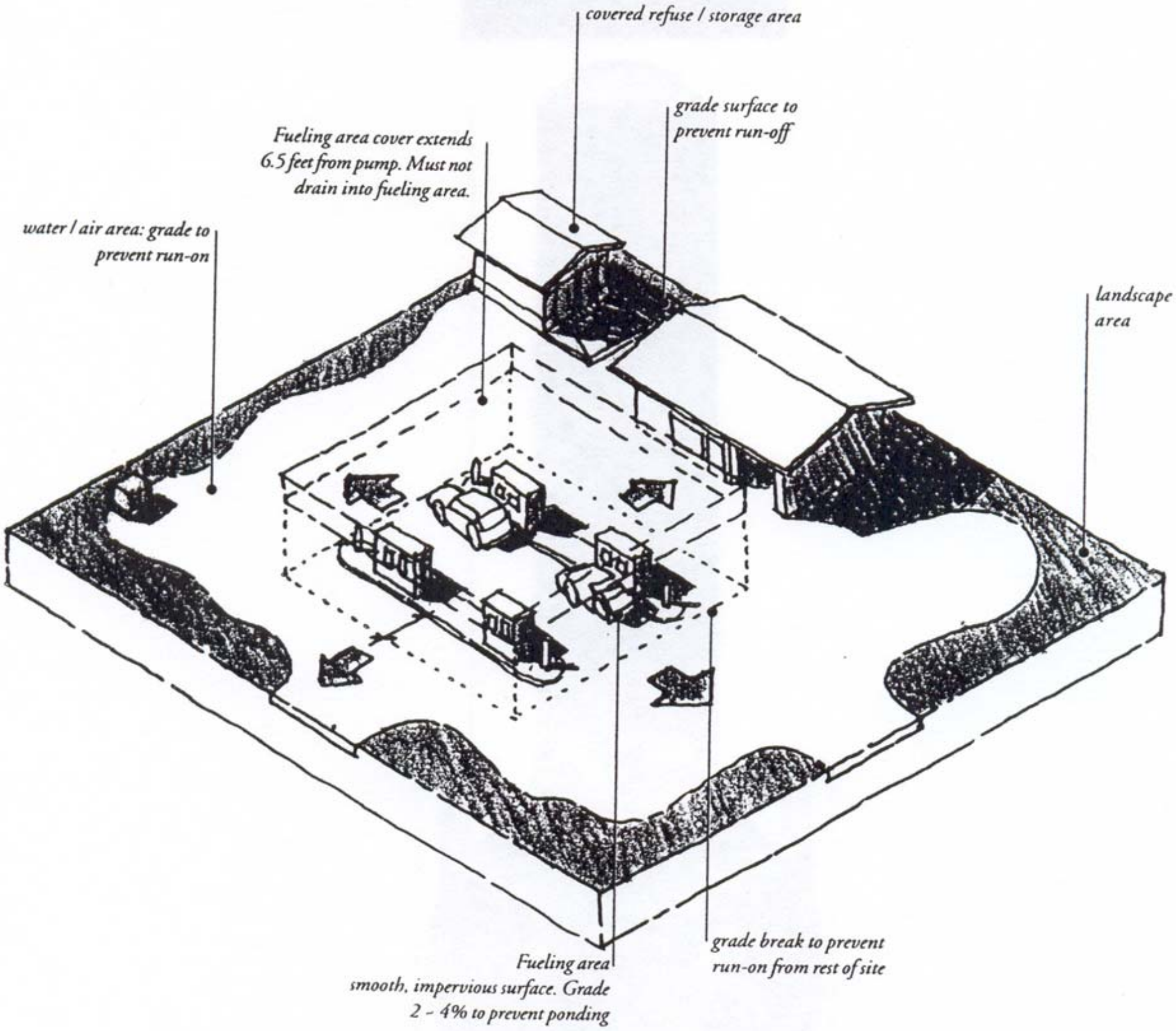
Small hillside site



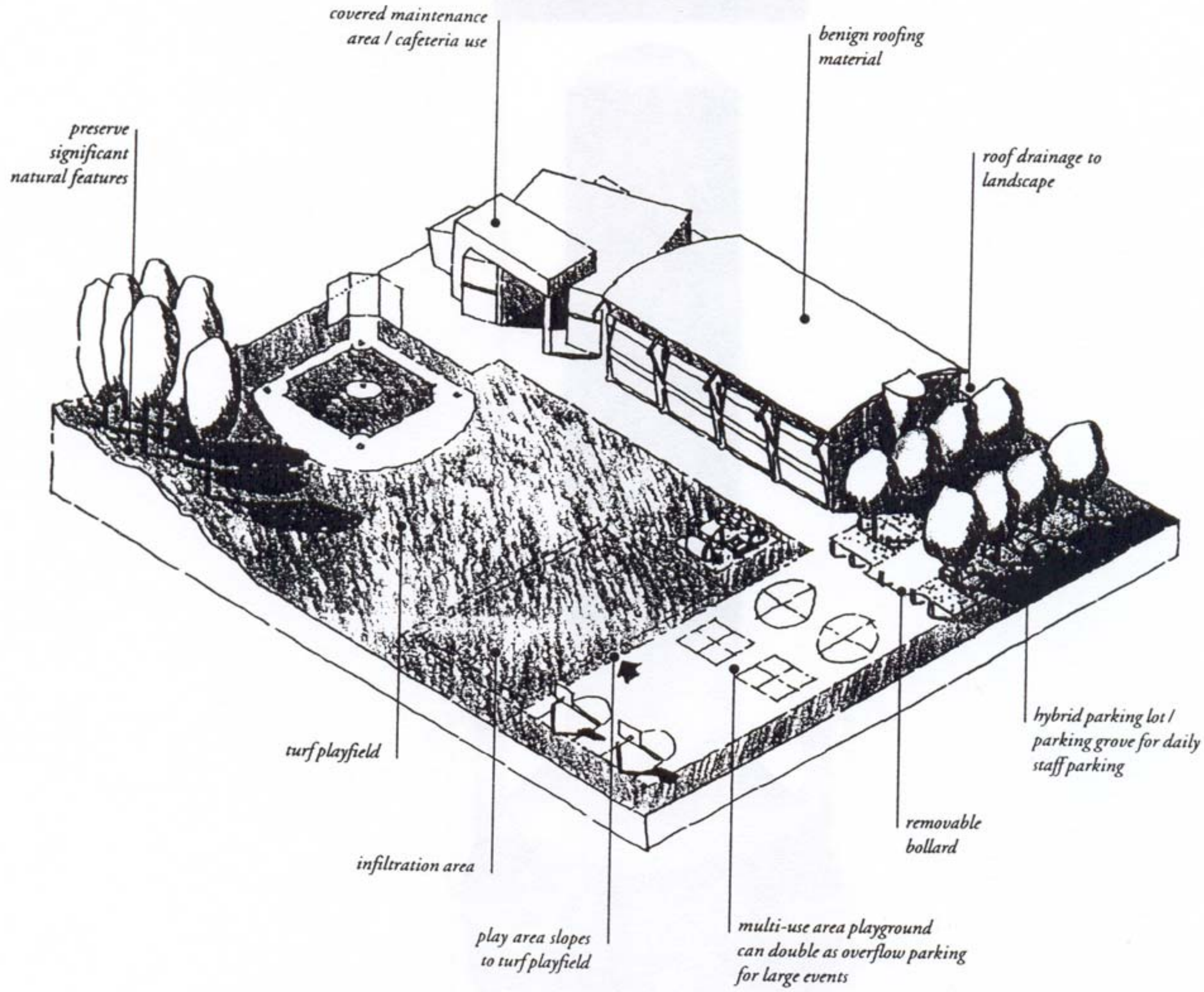
Large hillside site



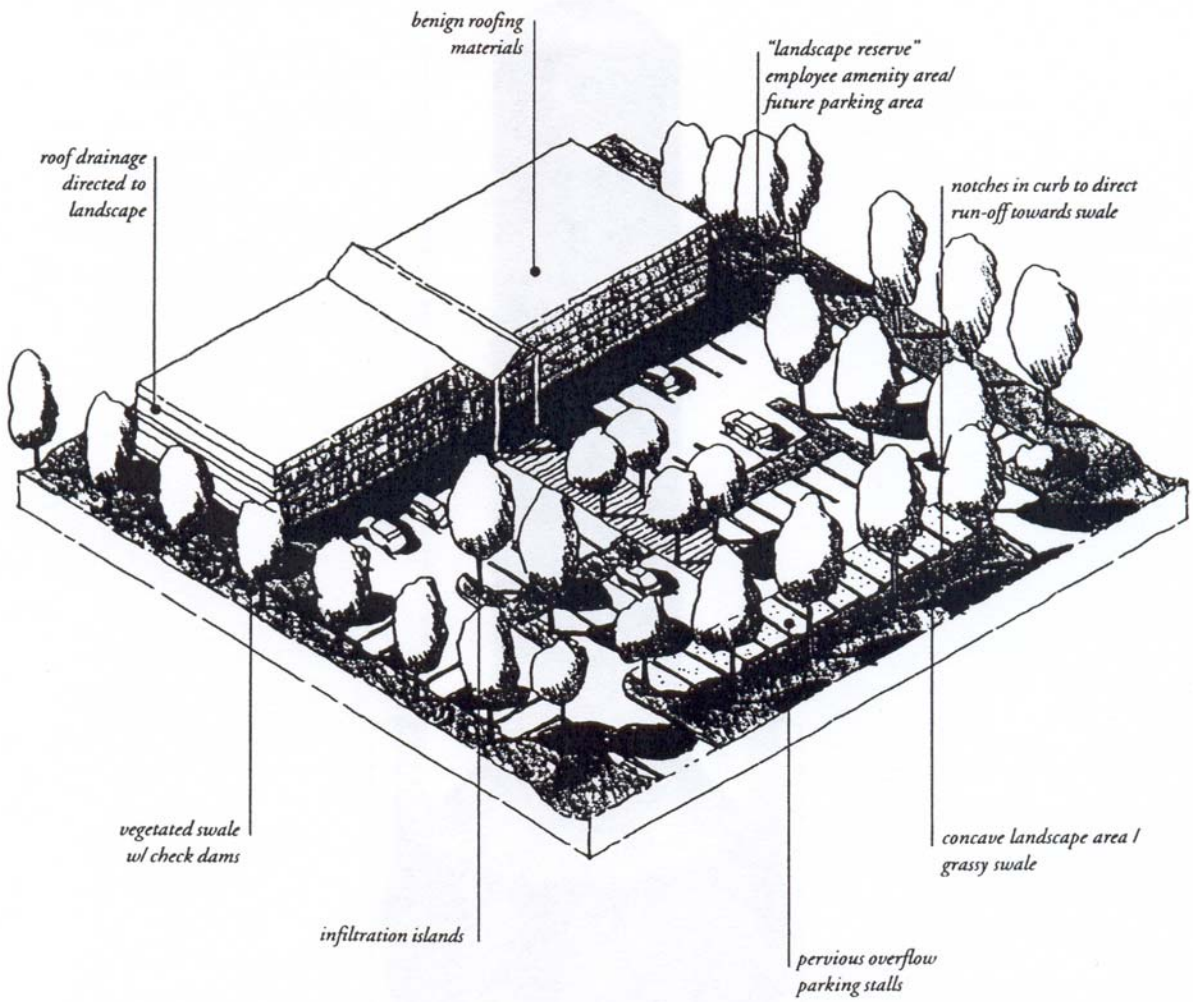
Gas station


covered refuse / storage area
grade surface to
prevent run-off
Fueling area cover extends
6.5 feet from pump. Must not
drain into fueling area.
water / air area: grade to
prevent run-on
landscape
area
Fueling area
smooth, impervious surface. Grade
2 - 4% to prevent ponding
grade break to prevent
run-on from rest of site

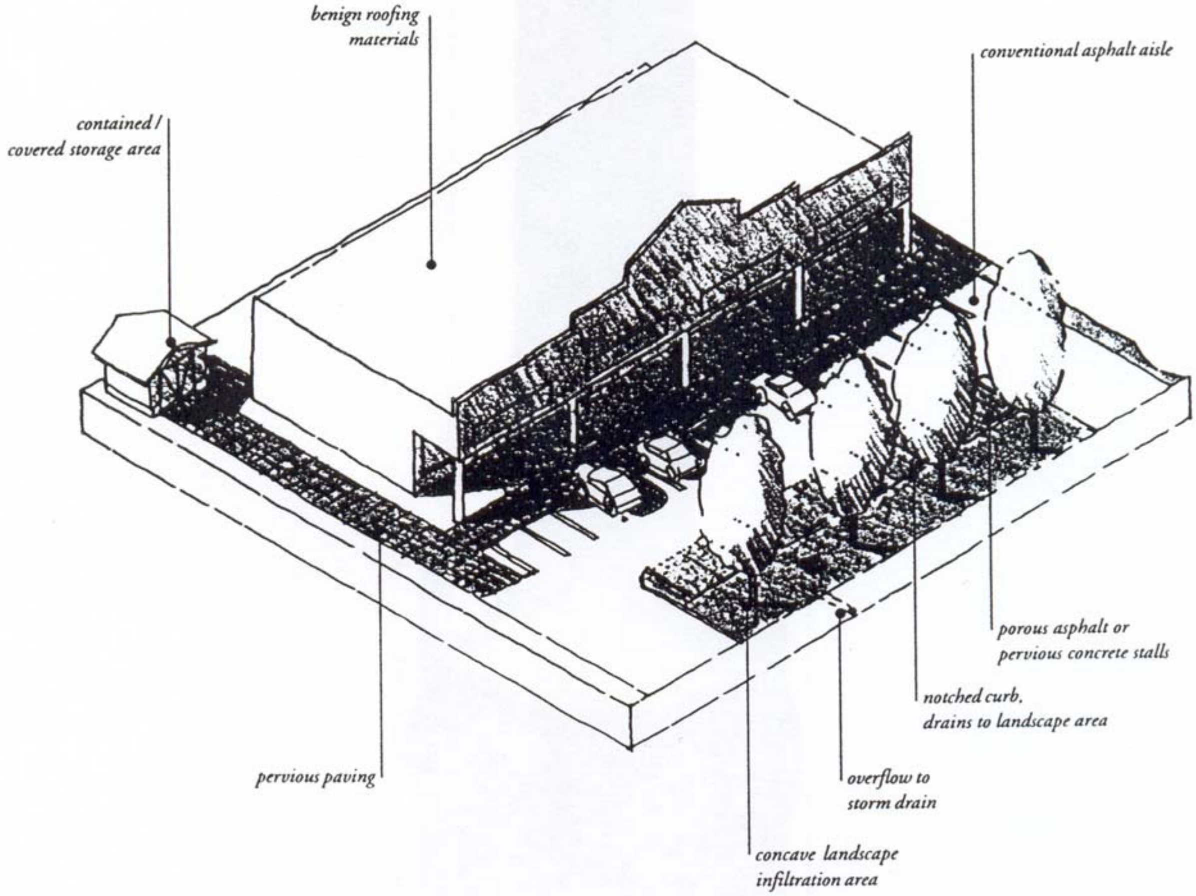
Schools and parks



Office building

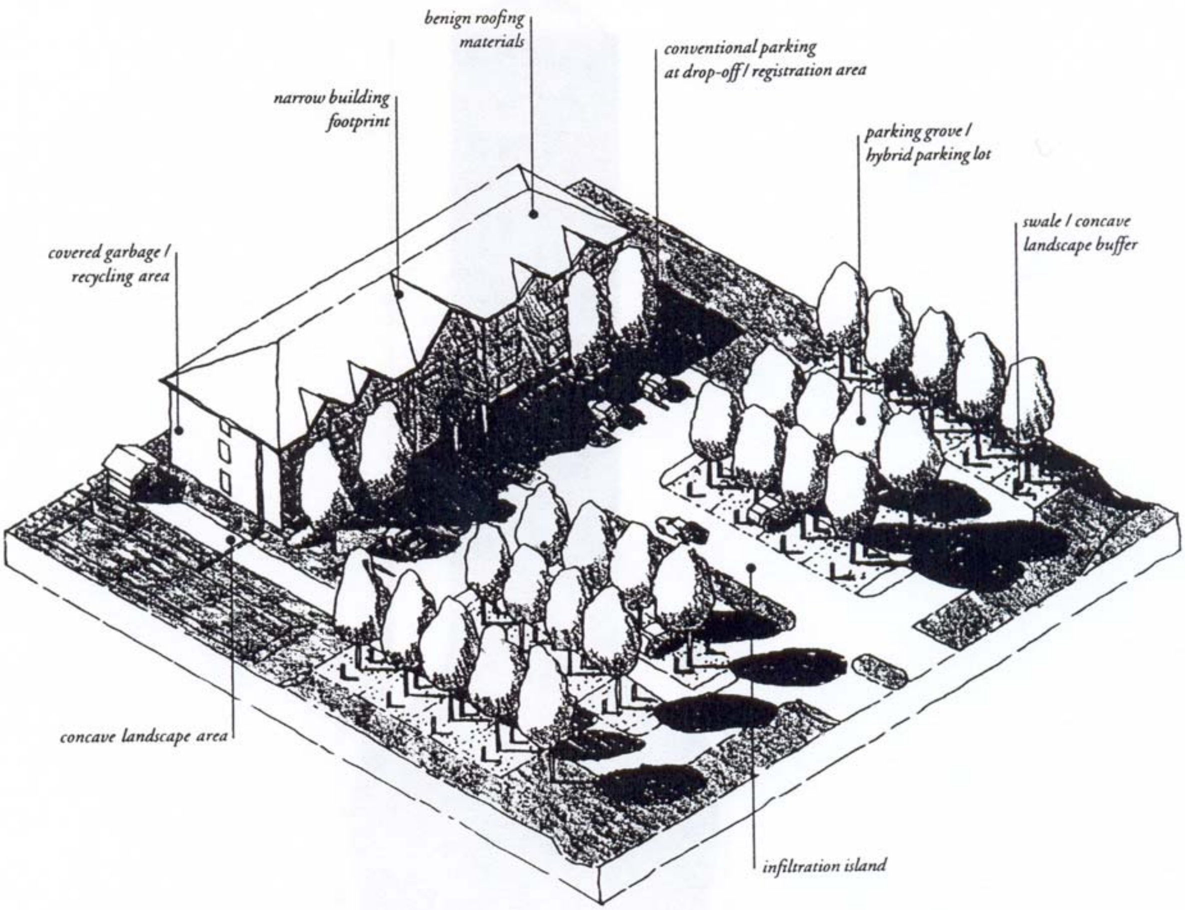


Strip Mall

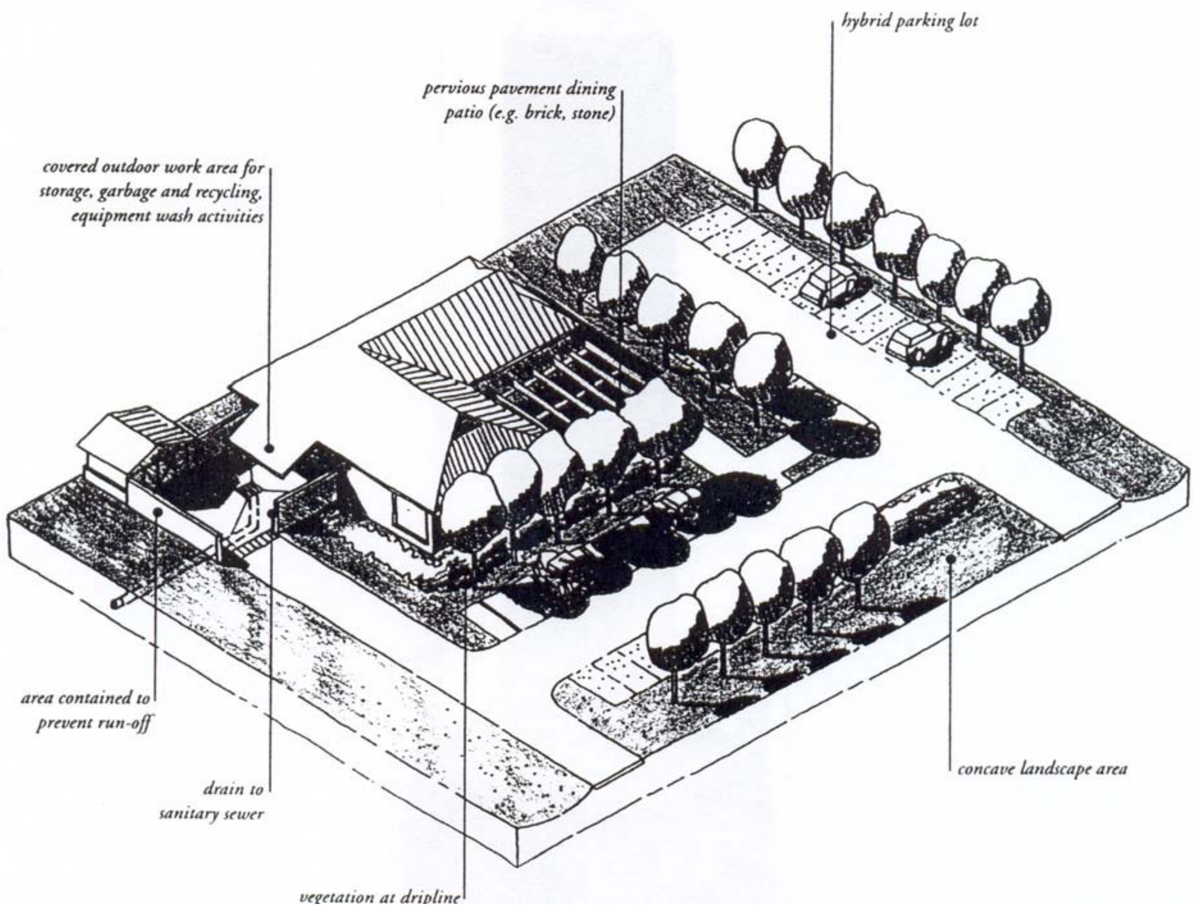


benign roofing materials
conventional asphalt aisle
contained / covered storage area
porous asphalt or pervious concrete stalls
notched curb, drains to landscape area
pervious paving
overflow to storm drain
concave landscape infiltration area

Hotel/motel


benign roofing materials
conventional parking at drop-off / registration area
narrow building footprint
parking grove / hybrid parking lot
swale / concave landscape buffer
covered garbage / recycling area
concave landscape area
infiltration island

Restaurant


hybrid parking lot
pervious pavement dining patio (e.g. brick, stone)
covered outdoor work area for storage, garbage and recycling, equipment wash activities
area contained to prevent run-off
drain to sanitary sewer
vegetation at dripline
concave landscape area

Appendix IV

(Glossary)

Glossary

Baseflow Streamflow during dry periods which is contributed to the stream channel by groundwater.

Best Management Practice (BMP) A method, activity, maintenance, procedure, or other management practice that reduces the amount of pollution entering a water body.

Biological Pertaining to the origin, growth, reproduction, and behavior of a living organism.

Chemical Pertaining to the composition and properties of a substance.

Cutbank A bank which forms a change of direction within a stream or river. Such banks are susceptible to erosion and often have steep slopes.

Depression Storage The ponding which occurs within a watershed during a precipitation event. Rainfall which is held in depression storage does not runoff and eventually infiltrates or evaporates.

Detention Structure A BMP which detains stormwater for a short time in order to allow the sediment pollution to settle out before being released to a receiving water body.

Drainage Basin (see Watershed) A land area bounded by high points, which drains all surface water into a single stream or other water body and has a common outlet for its runoff.

Duration The time in which a precipitation event lasts. Also refers to the length of time in which a runoff event will last.

Ecological Interaction between organisms and their environment.

Ecosystem A system formed by the interaction between a community of organisms with their environment.

EPA United States Environmental Protection Agency.

Evapotranspiration The process of transferring moisture to the atmosphere by the combined effects of evaporation of water and transpiration from vegetation.

Flood Plain The area along a stream or river which becomes flooded during the largest flood event possible.

Frequency A statistical measurement of the likeliness of occurrence.

Grade To disturb the natural soil and vegetation conditions within a development site.

Hydraulic The movement of water through a pipe or open channel.

Hydrology The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

Impervious To not be effectively (easily) penetrated by water. Examples include pavement, roof tops, compacted soils, and rock outcrops.

Infiltration The downward entry of water into the surface of the soil, as contrasted with percolation which is the movement of water through different soil layers.

Interception The process in which precipitation does not make it to the earth's surface. Interception is typically due to trees and other vegetation.

Mitigation *To lessen the severity of an environmental impact.*

Pervious A soil or material which allows the passage of water or other liquids.

Physical Pertaining to the properties of a substance.

Porous A substance which has many voids to store water or air.

Propagation Multiplication by natural reproduction.

Receiving Waters Lakes, rivers, streams, wetlands and coastal areas that receive runoff.

Retention Structure A BMP which is designed to store stormwater in an effort to allow most pollutants to either settle or be filtered by vegetation or other organisms before being released into the receiving water body at a later time.

Runoff Water from rain, melted snow, or agricultural or landscape irrigation that flows over the surface of the land.

Runoff Coefficient A coefficient which determines the portion of rainfall which will actually run off into the watershed and become stormwater. It ranges from 0 to 1.0 and is based on the permeability and water-holding capacity of the various surfaces within a watershed. Surfaces such as concrete and asphalt have high values (.75 ~ .95) and forested or other vegetated areas have very low values.

Sheetflow A flow condition in which the stormwater runoff is very shallow in depth and is spread uniformly over the land surface. Sheet flow is very non-erosive. However, it can only stay as sheetflow for a few hundred feet and turns into concentrated channel flow.

Slope The ratio of vertical elevation change to horizontal elevation change.

Stormwater Runoff Rain that flows off the surface of the land without entering the soil.

Unit Pavers Concrete grid or modular pavement whose spaces are filled with pervious materials such as sod, sand, or gravel.

Watershed (see Drainage Basin) The geographic region within which water drains into a particular river, stream, or body of water. Watershed boundaries are defined by the ridges which separate watersheds.

Weir A hydraulic structure which is designed to control and measure the flow of water.

Wetlands Low lying areas within a drainage system which are often saturated with surface water. Wetlands act as excellent natural filters within a drainage system.

2-Year Storm A precipitation event which has a 1:2 or 50% chance of occurring in any given year.

5-Year Storm A precipitation event which has a 1:5 or 20% chance of occurring in any given year.

100-Year Storm A precipitation event which has a 1:100 or 1% chance of occurring in any given year.

Appendix C. List of Wonderland Basin Land Owners

OWNER MAILING ADDRESSES

DATE: 11/01/99

			BOOK/ PAGE
0011161	BEDARD, RONALD W & LONI J	1N-07E SEC 28, PLATTED N1/2 OF E1/2 LOT 1 OF NE1/4NE1/4 LESS	42 6941
ND 1	6141 WILDWOOD DR	H1 LOT	
37 28 200-006	RAPID CITY, SD 577028967		AC= 4.960
0049039	BLACK HILLS CORPORATION	UTILITY SUB LOT 1	60 8505
NDCO	PO BOX 1400		
37 27 200-006	RAPID CITY, SD 57709		AC= 1.560
0006328	COYNE, SEAN P & LEAH R	MOON MEADOW ESTATES BLK 3 LOT 1 (ALSO IN SECTION 33 & 34)	67 93
CDO	3975 MOON MEADOWS		
37 28 376-001	RAPID CITY, SD 57702		AC= 3.460
0006328	SCHROEDER, ELDON E & LEONA G	LEGAL SAME AS ABOVE	59 9437
CDS	616 CLEVELAND		
	RAPID CITY, SD 57701		
0051985	F & D SHULTZ LIMITED PARTNERSHIP	1N-07E SEC 27, PLATTED TRACT 1 OF SE1/4NE1/4 LESS CONNECTOR	69 1407
ND 0	PO BOX 8110	SUB & LESS LOT H1	
37 27 200-010	RAPID CITY, SD 577098110		AC= 25.220
0002444	GODFREY, ROBERT W & BARBRA J	GODFREY ADDN LOT 1 (ALSO IN SECTION 26)	16 7195
NC 1	7675 S HWY 16		
37 27 400-002	RAPID CITY, SD 577019102		AC= 1.000
0046265	GODFREY, DANIEL C & PAMELA	GODFREY ADDN LOT 2	55 55
NC 1	7051 S HWY 16		
37 27 400-006	RAPID CITY, SD 57701		AC= 66.410
0046646	GODFREY, ROBERT W & BARBARA	GODFREY ADDN LOT 3	55 57
NC 1	7675 S HWY 16		
37 27 400-008	RAPID CITY, SD 57701		AC= 16.470
0046647	GODFREY, RAYMON L & GLADYS	GODFREY ADDN LOT 4	63 5843
NC 1	7601 S HWY 16		
37 27 400-009	RAPID CITY, SD 577018912		AC= 10.002
0046648	GODFREY, ROBERT W & BARBARA	GODFREY ADDN LOT 5	55 57
NC 0	7675 S HWY 16		
37 27 400-010	RAPID CITY, SD 57701		AC= 26.194
0011164	GUNDERSEN/GUNDERSEN-POWERS, EILEEN S & J	1N-07E SEC 28, PLATTED LOT B OF LOT 1 OF NE1/4NE1/4 & E135'	48 8633
ND 1	6260 CHOKECHERRY LN	OF N1/2W1/2 OF LOT 1 OF NE1/4NE1/4 & E115' OF S1/2W1/2	
37 28 200-003	RAPID CITY, SD 577028976	OF LOT 1 OF NE1/4NE1/4	AC= 3.160
0038737	HAMM, LEO D	1N-07E SEC. 27 LOT 1 OF NW1/4NW1/4 LESS LOT H-1, LO 5	4714
AC 0	6501 SHERIDAN LAKE RD	T 2 OF NW1/4NW1/4 LESS H1 LOT	
37 27 100-001	RAPID CITY, SD 57702		AC= 1.125
0043152	HAMM, LEO D	TED SUBD LOT D OF LOT 1 OF NE1/4NE1/4 LESS LOT P1	5 4714
AC 0	6501 SHERIDAN LAKE RD		
37 28 200-009	RAPID CITY, SD 57702		AC= .628
0048699	HAMM, LEO D	1N-07E SEC. 28 E1/2 OF LOT 2 OF NE1/4NE1/4; E1/2 OF 5	4714

			BOOK/ PAGE
AA 1	6501 SHERIDAN LAKE RD	LOT 1 OF SE1/4NE1/4 LESS LOT H1; E1/2 OF LOT 2 OF SE1/4NE1/	
37 28 200-010	RAPID CITY, SD 57702	4 LESS LOT H1; LOT 3 OF SE1/4NE1/4; E1/2NE1/4SE1/4	AC= 48.910
0039071	HAMM, UNA M	1N-07E SEC. 28 THAT PT OF SW1/4 LYING S OF SHERIDAN	36 4991
AA 0	720 1/2 CLARK ST	LAKE RD (LOT H2) LESS S E480' & LESS MOON MEADOWS SUBD & RO	
37 28 351-001	RAPID CITY, SD 577013653	W	AC= 40.348
0051681	HAUGO BROADCASTING INC	1N-07E SEC 27, UNPLATTED W1/2N1/2NE1/4 LESS UTILITY SUB, LES	80 6593
NDC2	306 E ST JOE	S LOS H1, H2 & H3 AND LESS ROW	
37 27 200-008	RAPID CITY, SD 57701		AC= 32.890
0011150	JOHNSON, JERALD L	1N-07E SEC 27, UNPLATTED E1/2N1/2NE1/4 LESS ROW	5 9240
AD 1	2001 GOLDEN EAGLE DR		
37 27 200-002	RAPID CITY, SD 577019102		AC= 40.000
0041444	LEO HAMM FAMILY RANCH LLC	1N-07E SEC. 28 NW1/4 LESS SE1/4NE1/4NW1/4 & LESS E1	58 5619
AA 0	6501 SHERIDAN LAKE RD	/2SE1/4NW1/4; NW1/4SW1/4; SE1/4SE1/4; SW/14SE1/4 LESS ROW	
37 28 100-001	RAPID CITY, SD 57702		AC=249.667
0048698	LEO HAMM FAMILY RANCH LLC	1N-07E SEC. 28 THAT PT E480' OF SE1/4SW1/4 N OF MOO	58 5619
AA 1	6501 SHERIDAN LAKE RD	N MEADOWS DR; SW1/4SW1/4 LYING N OF SHERIDAN LAKE RD; NE1/4S	
37 28 400-003	RAPID CITY, SD 57702	W1/4 LESS ROW; NW1/4SE1/4 LESS ROW; W1/2NE1/4SE1/4 LESS ROW;	AC=133.200
		N1/2NW1/4NE1/4	
0011162	MARSDEN, KAREN E	1N-07E SEC 28, PLATTED S1/2 OF E1/2 OF LOT 1 OF NE1/4NE1/4 L	46 9676
ND 0	1220 38TH ST	ESS LOT D OF LOT 1 OF TED'S SUBD	
37 28 200-007	RAPID CITY, SD 57702		AC= 4.320
0045170	OLSON, JAMES W & KAREN G	1N-07E SEC. 28 N33' X W273.2' OF LOT 1 OF NE1/4NE1/	57 7497
NC 0	6241 CHOKECHERRY LN	4	
37 28 200-001	RAPID CITY, SD 57702		AC= .210
0019717	OLSON, JAMES W & KAREN G	1N-07E SEC 28, PLATTED LOT A OF LOT 1 OF NE1/4NE1/4,W200' OF 175	183
ND 1	6241 CHOKECHERRY LN	S1 /2 OF LOT 1 OF NE1/4NE1/4	
37 28 200-002	RAPID CITY, SD 577028976		AC= 3.710
0049585	PARKER * LEO HAMM, SHELLIE L	1N-07E SEC. 28 SE1/4NE1/4NW1/4; S1/2NW1/4NE1/4; W65	63 6272
AA 0	6501 SHERIDAN LAKE RD	8' OF LOT 2 OF NE1/4NE1/4	
37 28 200-011	RAPID CITY, SD 57702		AC= 40.000
0011156	RUSHMORE CAR WASH INC	1N-07E SEC. 27 NW1/4NW1/4 LESS LOTS 1 & 2; SW1/4NE1	79 9580
AA 0	4921 CARRIAGE HILL CT	/4NW1/4; LESS LOTS H1,H2,P1 OF THE NW1/4NW1/4 (.258)	
37 27 100-002	RAPID CITY, SD 57702		AC= 48.512
0011155	RUSHMORE CAR WASH INC	1N-07E SEC. 27 N1/2NE1/4NW1/4; SE1/4NE1/4NW1/4	79 9580
AA 0	4921 CARRIAGE HILL CT		
37 27 100-003	RAPID CITY, SD 57702		AC= 30.000
0011154	SCHNEIDERMAN, KEITH G & SANDRA I	1N-07E SEC. 27 LOT A OF SE1/4NE1/4	53 2551
CDO	7001 S HWY 16		
37 27 200-004	RAPID CITY, SD 577019102		AC= 8.180
0011154	BACHMEIER, HENRY J & ELAINE D	LEGAL SAME AS ABOVE	

				BOOK/ PAGE
CDS	7001 S HWY 16 RAPID CITY, SD 577019102			
0049587 AA 0 37 28 200-013	SLOVEK & LEO HAMM, PENNIE L 6501 SHERIDAN LAKE RD RAPID CITY, SD 57702	1N-07E SEC. 28	SE1/4SE1/4NW1/4; S1/2SW1/4NE1/4; W65 8' OF LOT 2 OF SE1/4NE1/4	63 6276 AC= 40.000
0011165 ND 1 37 28 200-005	SWANGO, JAMES H & P J 6320 CHOKECHERRY LANE RAPID CITY, SD 57702	1N-07E SEC 28, PLATTED LOT C; W331.4' OF THE S1/2 LESS W200' ; W 20' OF THE E135' OF THE S1/2W1/2 (ALL OF LOT 1 OF NE1/4N E1/4)		76 8617 AC= 2.500
0011152 AA 0 37 27 100-004	TAYLOR, ROBERT L & ROMA L 23725 GONDOLA RD RAPID CITY, SD 57701	1N-07E SEC. 27	SW1/4NE1/4, S1/2NW1/4, NW1/4SE1/4,LE SS LOT H-1 & LOT P-1	AC=159.900
0011159 AA 0 37 27 300-001	TAYLOR, ROBERT L & ROMA L 23725 GONDOLA RD RAPID CITY, SD 57701	1N-07E SEC. 27	SW1/4	AC=160.000
0049040 NDCO 37 27 200-007	TOM-TOM COMMUNICATIONS 306 E SAINT JOSEPH ST RAPID CITY, SD 57701	UTILITY SUB LOT 2		76 5477 AC= .290
0049586 AA 1 37 28 200-012	WEISGRAM & LEO HAMM, KELLIE S 6531 SHERIDAN LAKE ROAD RAPID CITY, SD 57702	1N-07E SEC. 28	NE1/4SE1/4NW1/4; N1/2SW1/4NE1/4; W65 8' OF LOT 1 OF SE1/4NE1/4	63 6274 AC= 40.000

Account	Owner / Mailing Address	Legal Description	BOOK/ PAGE
0038272 ND 0 37 22 101-001	BURNS, ROBERT N & ELAINE K PO BOX 5266 SAN JOSE, CA 95150	AUTUMN HILLS SUBD TRACT A	68 2968 AC= .833
0037155 ND 1 37 15 151-001	DUNHAM, GEORGE F & NANCY W 3133 HEIDIWAY LN RAPID CITY, SD 577025296	VALLEY TRACT LOT 1 LESS LOT H1	40 6899 AC= 20.470
0046458 ND 0 37 16 226-002	DUNHAM, GEORGE F & NANCY W 3133 HEIDIWAY LANE RAPID CITY, SD 57702	1N-07E SEC 16, UNPLATTED E1/2NE1/4	62 8309 AC= 80.000
0046459 ND 0 37 16 400-012	DUNHAM, NANCY W 3133 HEIDIWAY LN RAPID CITY, SD 57702	1N-07E SEC 16, UNPLATTED W1/2NE1/4SE1/4	69 1063 AC= 20.000
0046460 ND 0 37 16 400-013	DUNHAM, NANCY W 3133 HEIDIWAY LN RAPID CITY, SD 57702	1N-07E SEC 16, UNPLATTED E1/2NE1/4SE1/4	68 7981 AC= 20.000
0010984 ND 0 37 15 200-008	EVANS PROPERTIES LP/BUTLERARTNERSHIP & B 817 9TH ST RAPID CITY, SD 577013518	1N-07E SEC 15, UNPLATTED NE1/4NE1/4	79 7893 AC= 40.000
0010956 ND 1 37 10 456-001	HOWE, TRUSTEE, EVERETT P PO BOX 9247 RAPID CITY, SD 577099247	1N-07E SEC 10, UNPLATTED SW1/4SE1/4, LESS BROADMOOR SUBDIVIS ION,LESS BLOCK 1 OF BROADMOORSOUTHWEST & LESS MOUNTAIN SHADO WS SUB	57 7598 AC= 9.190
0047620 ND 0 37 15 200-015	KIRKEBY/HALL, KENNETH L & PATRICK R 325 MOUNT RUSHMORE RD CUSTER, SD 57730	SANDSTONE RIDGE SUB LOT 1	68 4485 AC= 15.300
0007766 NCCO 37 34 200-002	KUCHENBECKER/SIEKMAN, KEITH & RICHARD 3211 STOCKADE DR RAPID CITY, SD 57702	PIONEER SUBD TRACT 1 (INCLUDES PT OF LOT B)	78 4023 AC= 20.160
0007767 NCCO 37 34 200-003	KUCHENBECKER/SIEKMAN, KEITH & RICHARD 3211 STOCKADE DR RAPID CITY, SD 57702	PIONEER SUBD TRACT 2	78 4023 AC= 41.830
0049047 ND 1 37 15 251-001	LEWIS/KIRKEBY, LARRY W & KENNETH L 2700 W MAIN ST RAPID CITY, SD 577028126	SPRINGBROOK ACRES TRACT SB LESS PT LOT 13A & LESS LOT 19R OF FAIRWAY HILLS PRD	40 1544 AC= 63.130
0020199 ND 0 37 15 176-004	PROPERTY RENTALS, INC 3800 FAIRWAY HILLS DR RAPID CITY, SD 577025320	ARROWHEAD VIEW TRACT H OF S1/2NW1/4 LESS PT OF LOT 1 & PT OF LOT 29 OF FAIRWAY HILLS PRD & LESS LOT H1	19 7812 AC= 2.290
0045065 ND 0 37 15 176-016	PROPERTY RENTAL, INC 3800 FAIRWAY HILLS DR RAPID CITY, SD 577025320	ARROWHEAD VIEW LOT 1 OF TRACT I	19 7812 AC= 2.100
0050668	RAPID CITY RETIREMENT RESIDENCE LLC	SANDSTONE RIDGE SUB LOT 3R	74 2752

			BOOK/ PAGE
NDC2	PO BOX 14111		
37 15 180-001	SALEM, OR 97309		AC= 3.010
0048479	SEVERSON, ANDREW J	PINE VIEW TERRACE TRACT 2; TRACT 4 LESS LOT H1	79 6670
ND 0	16810 BERNARDO CENTER DR		
37 16 400-017	SAN DIEGO, CA 92128		AC= 36.260
0011111	SPRINGBROOK ACRES WATER USERS ASSOC	1N-07E SEC 22, UNPLATTED UNPLATTED PORTION OF NE1/4 LESS PT	
ND 0	PO BOX 9182	LOT & THE UNPLATTED PORTION OF SE1/4NW1/4	
37 22 276-001	RAPID CITY, SD 577099182		AC= 83.170
0011240	TAYLOR, ROBERT L & ROMA L	1N-07E SEC. 34 W1/2NE1/4 LESS PT OF LOT H1; E1/2NW1	
AA 0	23725 GONDOLA RD	/4 LESS PT OF LOT H1	
37 34 200-001	RAPID CITY, SD 57701		AC=160.000
0051314	TLUSTOS, PATRICK	1N-07E SEC 15, PLATTED TRACT B OF NW1/4NE1/4 & NE1/4NW1/4 LE	39 6491
ND 1	3700 SHERIDAN LAKE RD	SS N40'; S260.6' OF TRACT C OF NW1/4NE1/4 & S80' OF N730' O	
37 15 127-004	RAPID CITY, SD 577025330	F NW1/4NE1/4 & NE1/4NW1/4 LYING E OF SHERIDAN LAKE RD	AC= 12.290

Lots Smaller Than 1 Acre

Lot #	Owner/Address	Acres
7 16 128-012	Avveduto, Frank L & Dorothy J	0.53
	4830 Riva Ridge Rd	
7 16 376-010	Beasley, Richard L & Lynn M	0.61
	6107 Wildwood	
7 16 205-013	Beaudette, Peter & Dorothy	0.10
	3629 Park Dr.	
7 16 205-003	Bishop, James G & Patricia A	0.08
	3501 Park Dr	
7 16 304-008	Braun, Warren L & Stefani G	0.76
	4320 Timberline Pl	
7 16 376-011	Brekhus, M J & Kristine J	0.59
	PO Box 1357	
7 16 251-046	Bryant, Robert S & Mary E	0.15
	3748 Olympic CT	
7 16 205-007	Burton, John C & Margot M	0.08
	3521 Park Dr	
7 16 254-002	Century Resources Inc	0.98
	PO Box 9279	
7 17 276-050	Chapel Lane Water Co.	0.83
	PO Box 2536	
7 16 377-005	Colerick, Ronald A & Deborah J	0.86
	628 Alta Vista Dr	
7 16 251-047	Creal, Tim H & Darla J	0.10
	3750 Olympic Ct	
7 16 251-044	Fischer, Douglas P & Colleen M	0.32
	3914 Park Dr.	
7 16 254-016	Fodness, Robert & Grace L	0.10
	3713 Park Dr	
7 16 353-002	Fritz, Thomas G & Pamela W	0.53
	4328 Timberlane Pl	
7 16 202-033	Graziano, Joe	0.13
	1719 W Main St	
37 16 202-034	Graziano, Joe	0.09
	1719 W Main St	
37 16 202-035	Graziano, Joe	0.09
	1719 W Main St	
37 16 202-037	Graziano, Joe	0.13
	1720 W Main St	
37 16 202-038	Graziano, Joe	0.15
	1721 W Main St	
37 16 202-039	Graziano, Joe	0.09
	1722 W Main St	
37 16 202-040	Graziano, Joe	0.12
	1723 W Main St	
37 16 202-030	Hanna Ferguson Co	0.45
	3612 Park Dr	
37 16 205-010	Hardin, Ray L & Gloria J	0.10
	3641 Park Dr	
37 16 205-014	Harvey, Edwin E	0.39
	122 Anamosa St	
37 16 254-008	Hauger, Carolyn J	0.09
	3817 Park Dr	
7 21 104-003	Hofman, Daniel P & Michaele S	0.92
	4215 Corral Dr	

Lots Smaller Than 1 Acre

Lot #	Owner/Address	Acres
37 16 254-010	Hondl, August L & Judith A	0.10
	3753 Park Dr	
37 16 254-011	Howard, Doranna B	0.10
	3747 Park Dr.	
37 16 328-008	J & J Anderson Trust	0.67
	4220 Wonderland Dr	
37 16 254-018	Johnson, Luann I	0.10
	3701 Park Dr	
37 16 205-004	Larson, Todd J & Barbara H	0.08
	3505 Park Dr.	
37 16 376-007	Miles/Oligmiller-Miles, Loren & Kathy	0.84
	4267 Starlite Dr.	
37 16 205-006	Naasz, Mary A	0.09
	3515 Park Dr	
37 16 152-002	Nelson, Allen G & Dianne D	0.54
	3902 Canyon Dr	
37 16 254-013	Nielsen, Don & Dixie	0.10
	3739 Park Dr	
37 16 205-008	Ohlmacher, Rosemary	0.09
	3525 Park Dr.	
37 16 205-005	Owen, Marilyn T	0.08
	233 Berry Blvd	
37 16 377-009	Peiffer, Theodore J & Elizabeth R	0.60
	4423 Forest Park Ct	
37 16 103-005	Quandt, Clarence F & Hannelore	0.43
	401 Cedar St	
	Box Elder, SD 57719	
37 16 205-011	Quintus, Maybelle A	0.10
	3637 Park Dr	
37 16 202-032	Rave, Trustee, Beverly J & AS T	0.17
	3528 Park Dr	
37 16 303-003	Riordan, John A & Mary	0.94
	4220 Penrose Pl	
37 16 251-043	Schat, Ralph D & Joyce I	0.32
	3912 Park Dr	
37 16 202-031	Shields, Michael J & Mary E	0.15
	3526 Park Dr	
37 16 378-001	Sobczak, Dwight A & Laura E	0.62
	7290 Tanager Dr	
37 16 251-045	Spanish Five Inc	0.39
	5006 Carriage Hills Dr	
37 16 177-009	Steele, Robert M	0.48
	PO Box 2105	
37 16 202-036	Swanson, Thure & Darlyne	0.13
	408 S 11th St	
	Beresford, SD 57004	
37 16 254-014	Tobin, Betty L	0.10
	3737 Park Dr	
37 16 254-017	Truhe, Clinton W & Lillie A	0.10
	3703 Park Dr	
37 16 351-002	United Nat'l Bank Trust: K Bushnell	0.75
	PO Box 1348	
	Sioux Falls, SD 57101	

Park Drive
Kent Hauger
Done
?

37 16 254

Century Resources
Don Wiesler Tsee Michael IN

Lots Smaller Than 1 Acre

Lot #	Owner/Address	Acres
37 16 205-012	Van Horn, David E & Cathy L	0.10
	3633 Park Dr	
37 16 376-008	Vidal, Patrick H & Karen A	0.75
	2618 Arrowhead Dr	
37 16 254-009	Ward, Birdie A & Duren K	0.09
	3811 Park Dr.	
37 16 254-015	Welsh, Judith C	0.10
	3715 Park Dr	
37 16 254-012	Western Management Corp	0.69
	2700 W Main	
37 16 254-019	Western Management Corp	0.69
	2700 W Main	
37 16 205-015	Western Management Corp	0.10
	2700 W Main	
37 16 205-016	Western Management Corp	0.10
	2700 W Main	
37 16 205-017	Western Management Corp	0.09
	2700 W Main	
37 16 205-018	Western Management Corp	0.09
	2700 W Main	
37 16 205-019	Western Management Corp	0.10
	2700 W Main	
37 16 205-020	Western Management Corp	0.10
	2700 W Main	
37 16 251-048	Wieseler, Michael O check	0.41
	2942 W Flormann St	
37 16 251-049	Wieseler, Michael O check	0.35
	2942 W Flormann St	

Built

who is western management corp
2700 W MAIN
RC SD 57702
Park Ridge

?

Michael Wieseler

Acreage Greater than 1 And Less than 5

Lot #	Owner/Address	Acres
37 16 377-002	Ashmore, Daniel E & Leslie M	1.322
	3814 Ridgemoor Dr	
37 16 377-011	Baxter, Ronald N & Ronda S	3.63
	5509 Meadowlark	
37 16 128-009	Beasley, Martin R & Kelly C	1
	4740 Summerset Dr	
37 21 101-003	Brugger, Kent & Peggy	2.37
	4116 Heidiway CT	
37 17 277-001	Donlin, Lorella	2.14
	4020 Penrose Pl	
37 16 353-010	Evans, Owen D & Kathleen D	4.15
	PO Box 9249	
37 16 304-001	Foye, Thomas H	3.16
	PO Box 2670	
37 17 251-003	Freimark, Lyle G & Marilyn S	2.79
	4012 Penrose Pl	
37 17 401-002	Gartner, F & Barbara A	3.74
	4011 Penrose Pl	
37 21 177-005	Gilbert, Ron A & Kary	1.31
	5150 Carriage Hills Dr	
37 17 276-051	Haefner, Robert C & Mary C	1.37
	4068 Canyon Dr	
37 16 128-008	Hammond, Dennis & Susan	1.06
	4870 Cliff Dr	
37 16 351-005	Herlihy, MD, John B & Patricia B	4.48
	4560 S Glenview Pl	
37 17 401-004	Herr, John E & Victoria	3.03
	4041 Penrose Pl	
37 16 377-004	Jones, Marjorie G & David L	2.69
	2413 Chancery Ct	
37 17 477-004	Kappelman, Ronald R & Janice L	1.34
	2407 Central Blvd	
37 16 205-002	Landmark Const. Corp.	2.46
	~~PO Box 3037~~	
37 16 205-009	Lewis/Andrew, Larry M & Chester J	1.07
	PO Box 9129	
37 21 103-006	M G Oil Company	1.57
	PO Box 1006	
37 16 152-016	Martin, Willard J & Mary	2.55
	3902 Ponderosa Trl	
37 17 476-003	Martley, Thomas W & Lavonne M	4.97
	4401 N Glen Pl	
37 16 304-011	McGuigan, Patrick M & Arlene J	1.61
	4102 Carriage Hills Dr	
37 16 400-006	Milliam, Lester M & Clarice	3.22
	3740 Corral Dr	
37 16 101-006	Morril, S	1.78
	3601 Ridge Dr	
37 09 381-013	Mueller, Stan F & Jacquelin P	1.266
	1409 E 62nd St	
	Sioux Falls, SD 57108	
37 16 326-007	Nelson, Allen G & Dianne D	2.66
	4231 Starlite Dr	
37 17 401-003	Petersen, James A & Bonny J	3.26
	4021 Penrose Pl	
37 16 151-004	Quandt, Clarence F & Hannelore	1.39
	401 Cedar St	
	Box Elder, SD 57719	
37 09 454-001	Raben, Julie G	1.92
	1417 5th St	
37 21 127-004	Riemenschneider, JR, Albert L	1.17
	4051 Corral Dr	
37 16 176-008	Rose M Kopriva Revocable Trust	1.41
	4780 Cliff Dr	
37 16 127-003	Rose M Kopriva Revocable Trust	3.89
	4780 Cliff Dr	
37 16 353-014	Samuelsen/Christenson, Ruth A & Grace C	4.69
	4531 S Glen Pl	
37 16 176-002	Schuttler, Richard A & Cynthia S	1.271
	~~3404 Park Dr~~	
37 16 251-036	Severson, Trust, ~~Jean~~	1.64
	3114 Wonderland Dr Call A.D.	
~~37 16 376-012~~	~~Stotz, Mark E & Paula~~	1.16
	4273 Rosemary Ln	
37 17 278-004	Thompson, Judith M	1.87
	4031 Canyon Dr	
37 16 205-021	Harvey, Edwin E	1.52
	122 Anamosa St	
37 16 377-012	Zavita, Paula J	3.61
	4811 Riva Ridge Rd	

? Larry Lewis

254 022
10.9 ac

Appendix D. Public Forum Outline

PUBLIC INFORMATION FORUM
STORMWATER MANAGEMENT ISSUES

1. Purpose of Form

    1.1. Raise Public Awareness of Stormwater Management Issues in Rapid City
    1.2. Provide Public with Resources and Information Concerning Stormwater Management Issues
    1.3. Begin the Process of Maintaining/Improving the Quality of Surface Water in the Rapid City Area

2. Watershed Approach

    2.1. Takes holistic approach to surface water quality and potential impacts to surface water quality and quantity from all facets within a watershed
    2.2. Define Watershed

3. Surface Water Quality

    3.1. Define Surface Water Quality
    3.2. Why is it Important
        3.2.1. Maintain Quality of Life in Rapid City
        3.2.2. Environmental Importance
            3.2.2.1. Rapid Creek as a Recreational and Cultural Resource to Rapid City
            3.2.2.2. Aesthetics
        3.2.3. Economic Importance
        3.2.4. Legal Requirements
    3.3. What affects Surface Water Quality
        3.3.1. Everyday Life and Activities
        3.3.2. Development
        3.3.3. Mother Nature
    3.4. Pollutants
        3.4.1. Physical (Sediments)
        3.4.2. Biological
        3.4.3. Chemical
    3.5. Impacts From Sediments and Other Run-off
        3.5.1. Sediment Loading
        3.5.2. Examples of Current Data on Impacts to Rapid Creek (i.e. coliform, TSS, BOD…)

4. Stormwater Management
    4.1. One Part of the Watershed Approach
    4.2. Define Stormwater
    4.3. Why is it Important to Control Stormwater
        4.3.1. Regulatory Requirements
            4.3.1.1. Federal

4.3.1.1.1. NPDES Phase II
4.3.1.2. State
4.3.1.3. Local
4.3.1.3.1. Regulations Must have Teeth and Must be Enforced
4.3.2. Preserve Environment
4.3.2.1. Protect Local Resources
4.3.2.2. Maintain Quality of Life
4.3.2.3. Protect Human Health and Property
4.4. Ways to Manage Stormwater
4.4.1. Conventional Approaches
4.4.1.1. Detention Structures
4.4.1.2. Retention Structures
4.4.1.3. Lined Channels
4.4.2. Non-Conventional Approaches
4.4.2.1. Open Drainage Ways
4.4.2.2. Low Impact Construction
4.4.2.3. Low Impact Development
4.4.2.4. Best Management Practices (BMPs)

5. Wonderland Drainage Project
5.1. Research Project
5.2. Purpose
5.2.1. Study Costs and Benefits of Low Impact Development and BMPs
5.2.2. Provide One Avenue for the City of Rapid City to Meet Upcoming Regulatory Requirements and Maintain Quality of Life in Rapid City
5.3. Joint Effort Between SDSM&T and City of Rapid City
5.3.1. Team Members
5.3.2. Funding
5.4. Goals
5.5. Tasks
5.5.1. Develop model for Wonderland Basin
5.5.2. Monitor Surface Water Quality
5.5.3. Design and Construct Surface Water Quality Structure within the Wonderland Basin
5.5.4. Monitor Two Development Sites
5.5.5. Summarize and Present Findings

6. What are Low Impact Development and Best Management Practices
6.1. Purpose
6.1.1. Minimize the Impact of Construction and Development on Surface Water Quality and Quantity
6.1.1.1. Focus is on Non-Point source Impacts
6.1.1.2. Contain/Reduce First Flush
6.1.1.3. Reduce Sediment Loading
6.1.1.4. Impacts do Not Stop at Construction Boundary
6.1.1.5. Reduces Quantity of Surface Water from Developed Areas

6.1.1.6. Proactive vs. Reactive Approach

7. Why Implement Low Impact Construction and BMPs
    7.1. Regulatory Requirements
    7.2. Preserve Environment

8. Best Management Practices
    8.1. Focus is On Long Term Installations
    8.2. Types of BMPs
        8.2.1. Detention Ponds
        8.2.2. Natural Channelization
        8.2.3. Low Impact Development

9. Low Impact Construction and Development
    9.1. Focus is on Containing Sediments and other pollutants On-Site
    9.2. Types of Practices
        9.2.1. Bioretention
        9.2.2. Infiltration Trenches
        9.2.3. Dry-Wells
        9.2.4. Roof-top Storage
        9.2.5. Vegetative Filter Strips
        9.2.6. Level Spreaders
        9.2.7. Rain Barrels
        9.2.8. Cisterns
        9.2.9. Swales
        9.2.10. Minimization of Impervious Area
        9.2.11. Strategic Clearing and Grading
        9.2.12. Vegetated Buffers
        9.2.13. Engineered Landscaping
        9.2.14. Reduction of curb and gutter and roadway
    9.3. Devices must be Properly Installed and Maintained
    9.4. Are used in conjunction with and go beyond conventional Sediment and Erosion Control Practices such as silt fences, haybales, etc.
    9.5. Benefits
        9.5.1. Maintain or Improve Surface Water Quality
        9.5.2. Reduce Run-off from Construction Sites and Developed Areas
    9.6. Costs
        9.6.1. Short Term
        9.6.2. Long Term

10. Education
    10.1. Public
    10.2. Government Employees
    10.3. Developers
    10.4. Contractors
    10.5. Planners/Designers/Engineers

11. Goals
    11.1. Make Practices Common Place
    11.2. Maintain/Improve Surface Water Quality in Rapid City

12. Funding
    12.1. State and Federal Funds
    12.2. Polluter Pays
        12.2.1. Construction application Fees
        12.2.2. Cost Incentives for use of Low Impact Construction and BMPs
        12.2.3. Surety Bonds or Irrevocable letter of Credit
    12.3. All Who Benefit Pay
        12.3.1. Storm Water Utility

13. Resources
    13.1. Practices in Other Communities
    13.2. List of Publications and Websites
    13.3. Public Participation
        13.3.1. Erosion Control Patrol
        13.3.2. Soil Watch Program
        13.3.3. Sediment Patrol
        13.3.4. Soil Stewards
        13.3.5. Citizen Environmental Conservation Board

14. Summary
    14.1. Improve/Maintain Surface Water Quality and Way of Life in Rapid City
    14.2. Beginning of a Very Long Process
    14.3. Research Project

Appendix E. Preliminary BMP Design Plan and Specifications

Preliminary Erosion Control Project Notes

Project location:
The project is located in Southwest Rapid City, South Dakota, Approx. ½ mile Southeast of Canyon lake, on the west side of Park Drive, approx 100 ft. south of the intersection with Glenwood Drive (SW ¼ of SE ¼ of Sect. 9, T1N, R7E, Black Hills Meridian).

Stationing:
Stationing begins with 0+00 at the inlet face of the parapet of the 8 x 6 box culvert, located downstream of the drop structure, and proceeds upstream.

Description of work:

1. Remove silt and debris from existing channel from station 0+00.00 to station 0+30.00.
2. Construct open channel transition from station 0+30.00 to station 0+50.00.
3. Construct open channel sta. 0+50.00 to sta. 1+22.62.
4. Construct rock – filled wire basket drop structure from station 1+22.62 to station 1+85.30.
5. Construct open channel transition from station 1+85.30 to station 2+18.00.
6. Fertilize, seed, and install straw mat on all disturbed area.

Channel reshape:
The existing channel geometry upstream of the structure requires narrowing to transition to the drop structure. The existing channel downstream of the drop structure requires widening to transition the structure outlet to the existing channel. Widening is to be done by constructing open channel from the structure outlet geometry downstream through the curve, and then transitioning to the existing geometry.

Limits of construction:
From station 0+00.00 (the upstream face of the parapet wall (headwall) of the 8’ x 6’ box culvert), then upstream to station 2+18.00, the west edge of the sidewalk along the west side of Park Drive, and 50 ft. left (looking downstream) of stream centerline.

Excess earth:
Excess earth material may be wasted in the area shown on sheet #3, not to exceed the grade and lines as shown on the plan and cross sections. The waste shall be graded and blended to the existing topography and seeded as described in the Specifications. No waste haul payment will be made.

Utilities:
It is the contractor’s responsibility to locate and preserve existing utilities associated with the work.

Specifications

I. Standard Specifications

The Standard Specifications apply and are found in the current edition of *Standard Specifications for Public Works Construction*, City of Rapid City.

II. Project Specific Specifications

In addition to the Standard Specifications, the following also apply:

A. Grubbing:

One 18”, nine 8”, and eight 6” trees, plus brush and grass must be removed from the structure area. one 14” tree is to be removed from channel centerline upstream of the box culvert at approx. sta. 0+60.00. Silt and debris is to be removed from station 0+00.00 to station 0+30.00.

B. Preservation:

The trees nearest to the sidewalk along Park Drive are to be preserved wherever possible.

E. Soil balance:

Cut quantity is approx. 308 yd^3; fill quantity is 153 yd^3. The net excess is 155 yd^3. There is room for this excess material adjacent to the structure on the street side (Sheet 3). It shall be graded and blended to the existing topography and replanted with grass, not to exceed the lines and grade shown on the plan and cross sections.

F. Gabion construction:

Special consideration is given to the angled joints adjacent to the filter fabric. The full velocity of the flow is kept from the filter fabric by filling the gap with loose rock (Sheet 2). The filter fabric is to be continuous under the entire structure, daylighting at final grade, flush with the top surface of the gabion, and clipped to the top corners of the baskets. If the fabric is torn during construction, a patch may be laid over the tear, overlapping 30” minimum. Seams are to be laid perpendicular to flow, overlapped 30 in. minimum, with the upstream sheet on top. Specified: Amoco# 4516 non-woven geotextile or equivalent.

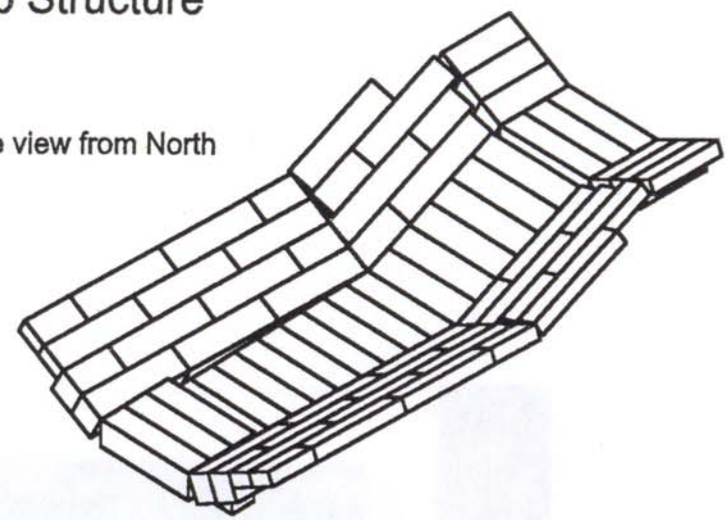
D. Revegitation:

All disturbed areas will be reseeded and covered with degradable straw matting to control erosion during turf growth. Specified: North American Green #S150 straw mat or equivilant.

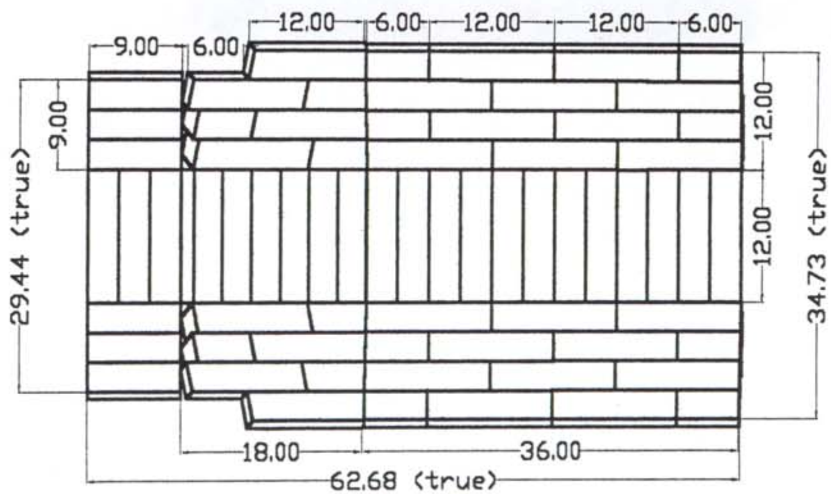
Seed is to be applied at a rate of 6 to 7 lb/1000 ft^2. Straw matting is to be immediately installed and anchored with 6 to 8 in. wire “staples” spaced 3 ft along the edges, and on a 3 foot grid elsewhere. The seeded areas are to be watered within 12 hours to relax the mat. Specified: A local grass mix termed “black hills blend” and “black hills reclamation mix” synonymously. Fertilize per the Standard

Wonderland Basin Drop Structure

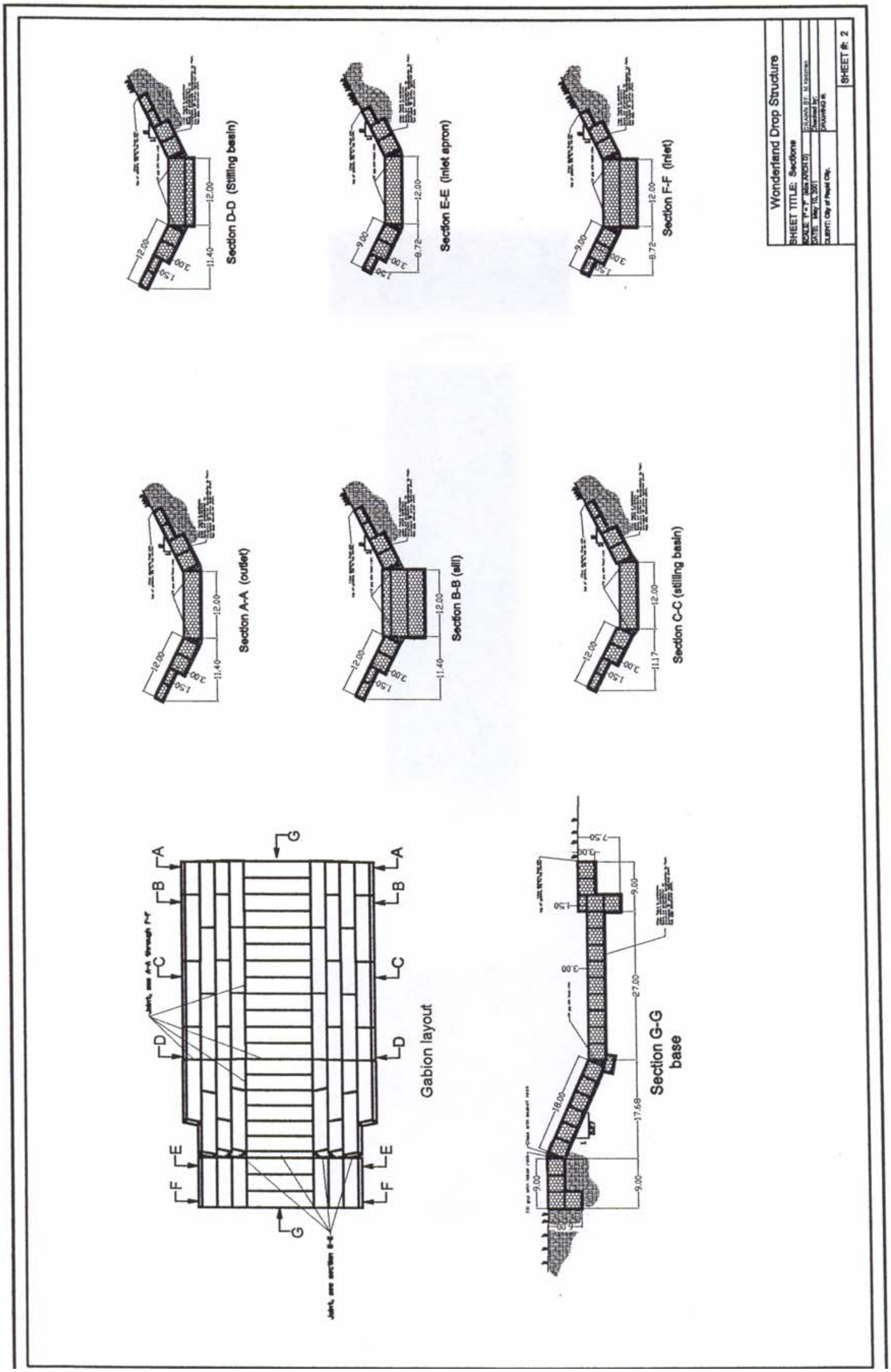
Wireframe view from North



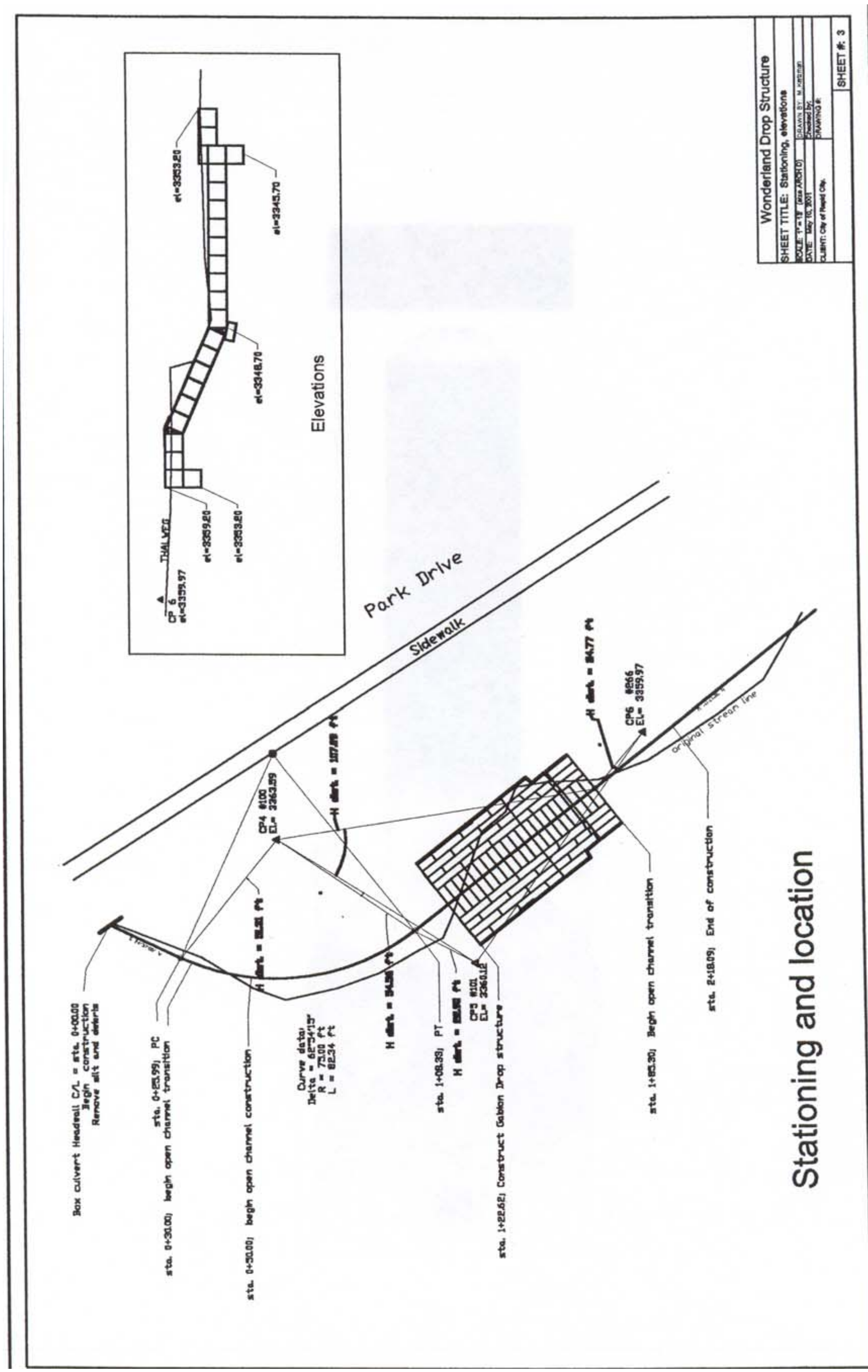
Gabion layout

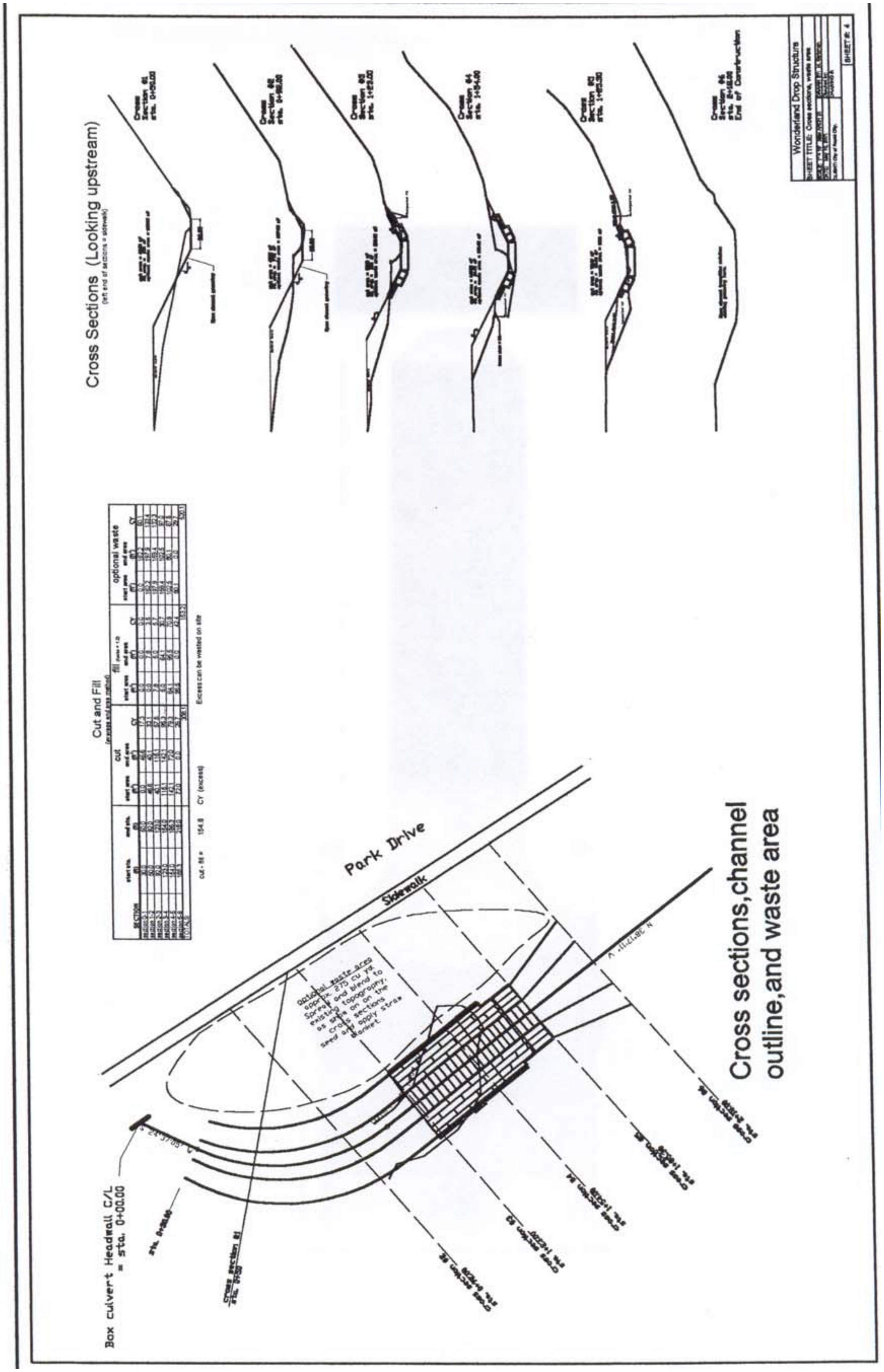


Wonderland Drop Structure	
SHEET TITLE: Notes, Specifications	
SCALE: 1" = 8' (Size ARCH D)	DRAWN BY: M. Kertzman
DATE: May 10, 2001	Checked by:
CLIENT: City of Rapid City.	DRAWING #:
	SHEET #: 1



Section D-D (Stilling basin)
Section E-E (Inlet apron)
Section F-F (Inlet)
Section A-A (outlet)
Section B-B (sill)
Section C-C (stilling basin)
Gabion layout
Section G-G
base
Wonderland Drop Structure
SHEET TITLE: Sections
SHEET #: 2


Wonderland Drop Structure
SHEET TITLE: Stationing, elevations
SHEET #: 3
Elevations
THALWEG
Park Drive
Sidewalk
original stream line
Box culvert Headwall C/L = sta. 0+00.00
Begin construction
Remove silt and debris
sta. 0+30.00; begin open channel transition
sta. 0+50.00; begin open channel construction
Curve data:
sta. 1+08.33; PT
sta. 1+22.62; Construct Gabion Drop structure
sta. 1+85.30; Begin open channel transition
sta. 2+18.09; End of construction
Stationing and location


Cross Sections (Looking upstream)
Cut and Fill
Excess can be wasted on site
Park Drive
Sidewalk
Cross sections,channel outline,and waste area
Box culvert Headwall C/L = sta. 0+00.00
Wonderland Drop Structure