SUSTAINABLE MANAGEMENT OF WATER RESOURCES ON CAMPUS: THE CASE OF IZMIR INSTITUTE OF TECHNOLOGY

A Thesis Submitted to
the Graduate School of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in Urban Design

by
Pelin ULUSOY

June 2011
İZMİR

We approve the thesis of **Pelin ULUSOY**

_____
Assist. Prof. Dr. Nicel SAYGIN
Supervisor

_____
Prof. Dr. Cemal ARKON
Committee Member

_____
Prof. Dr. Gökmen TAYFUR
Committee Member

27 June 2011

_____
Assoc. Prof. Dr. Semahat ÖZDEMİR
Head of the Department of
Regional Planning

_____
Prof. Dr. Durmuş Ali DEMİR
Dean of the Graduate School of
Engineering and Sciences

ACKNOWLEDGMENTS

I am very grateful to many people for their help in preparing this thesis. Firstly, I would like to express my gratitude to my supervisor, Assist. Prof. Dr. Nicel SAYGIN for her great inspiration, patience and professional help and advices in every stage of the thesis.

My special thanks go to Dr. Çiğdem TARHAN for her special concern for the case part of the thesis and motivations and advices of her for effective demonstrations.

In terms of collecting the data for the case study, I would like to thank to the academic personal of construction department of Izmir Institute of Technology and Sadettin Türkekul for their helps to get the archieve datas. Especially, thank to Prof. Dr. Gökmen TAYFUR and Assoc. Prof. Dr. Alper BABA to share their studies and professional knowledges with me and lastly to my committee members of Prof. Dr. Gökmen TAYFUR, Prof. Dr. Cemal ARKON, Assoc. Prof. Dr. Alper BABA for their contributions to the thesis.

I owe my deepest gratitude to my family to support me in every stage of the thesis from beginning to the end. I want to thank them for their self-devotion and care. Their endless motivation for me to reach.

Lastly, I offer my regards to my friends, colleagues and everyone who supported me during this period.

ABSTRACT

SUSTAINABLE MANAGEMENT OF WATER RESOURCES ON CAMPUS: THE CASE OF IZMIR INSTITUTE OF TECHNOLOGY

The concept of sustainability plays an essential role in university campus development. This study specifically focuses on sustainable water resources management among extensive sustainable campus principles. Water is a non-renewable asset for our increasingly arid geography due to reasons such as global warming. The sustainable management of water resources includes capture and reclamation of rainwater/stormwater, treatment of wastewater, protection and enhancement of groundwater quality, protection and rehabilitation of natural water bodies (creeks, streams, rivers, lakes and others) and efficient landscapes.

Green infrastructure techniques prevent runoff problems due to conventional drainage such as flood and water quality degradation; and provide natural drainage and infiltration, improve water quality, prevent floods and enhance ground water. In this study rainwater/stormwater is treated as a non-renewable resource instead of wastewater. This water resource can be captured and reused for different purposes such as irrigation, groundwater recharge, green corridors and landscape amenity by integration of rainwater/stormwater features into the site in an aesthetically pleasing way. Additionally, use of green infrastructure techniques reduces the consumption of clean water. This study develops strategies for use of green infrastructure techniques and recommendations to guide the implementation of these strategies. As a case study, recommendation of green infrastructure techniques with efficient landscape for entire Izmir Institute of Technology (IYTE) Campus located in Gülbahce-Urla (Izmir) has been developed.

ÖZET

KAMPÜS SU KAYNAKLARININ SÜRDÜRÜLEBİLİR YÖNETİMİ: İZMİR YÜKSEK TEKNOLOJİ ENSTİTÜSÜ ÖRNEĞİ

İklim değişiklikleri ve çevresel etkilerin en aza indirgenmesi amaçlı olarak ortaya çıkan sürdürülebilirlik kavramı dünya genelinde üniversite kampüslerinin tasarımında etkin olarak rol oynamaktadır. Sürdürülebilir Kampüs kavramı ekolojik çevreye duyarlı ve çevreye olan etkilerini en aza indirgemeyi kendisine amaç edinmiş olan kampüsler için kullanılmaktadır.

Bu çalışma geniş kapsamlı olan Sürdürülebilir Kampüs ilkeleri içerisinden spesifik olarak su kaynakları yönetimi konusuna eğilmektedir. Küresel ısınma gibi nedenlerle gitgide kuraklaşan coğrafyamızda su kaynaklarının çok değerli olduğu bir gerçektir. Bu nedenle su yönetimi konusunun ön plana alınması kaçınılmazdır. Sürdürülebilir bir çevre için su yönetimi konusunun içerisinde yağmur sularının kazanılması, kullanılmış/atık suyun geri dönüştürülmesi, yeraltı sularının niteliklerinin korunması ve beslenmesi, doğal su koridorlarının (dere ve nehirler) korunması, sürdürülebilir peyzaj alanlarının oluşturulması, içilebilir suyun kullanımının minimize edilmesi gibi konular yer almaktadır.

Yeşil Altyapı, yüzey suyu akışını geleneksel drenaj uygulamalarının oluşturduğu problemlerden (sel ve su baskınları, su kalitesinde bozulma, maliyet) sakınarak çevreyle uyumlu bir biçimde (doğal drenajı sağlar, su kalitesini artırır, sel ve su baskınlarını önler, yeraltı suyunu besler) ele alma yöntemidir. Bu çalışmada yağmur suyunun bir atık olarak sınıflandırılması yerine ekosisteme katkıda bulunacak ve yere düştüğü arazide farklı amaçlara (tuvalet rezervleri, sulama, rekreasyon koridorları, peyzaj elemanı vb) hizmet edecek biçimde geri kazandırılmasını sağlayacak az maliyetli ve yeşil altyapı elemanlarının kullanılması yönünde bir strateji geliştirilecek ve bu stratejilerin uygulanmasında rehber oluşturacak öneriler üretilecektir.

Çalışma alanı olarak Gülbahçe-Urla (İzmir) mevkiinde yer alan İzmir Yüksek Teknoloji Enstitüsü (İYTE) kampüsünün mevcut durumu su yönetimi açısından irdelenerek kampüs genelinde açık alan ve altyapı uygulamaları için öneriler geliştirilecektir.

TABLE OF CONTENTS

LIST OF FIGURES ix

LIST OF TABLES xviii

CHAPTER 1. INTRODUCTION. 1

1.1. Background 1

1.2. Problem Definition 2

1.3. Aim and Objectives 3

1.4. Methodology 4

1.4.1. Literature Survey and Review 4

1.4.2. Case Study 4

1.5. Organization 7

CHAPTER 2. CAMPUS SUSTAINABILITY AND SUSTAINABLE CAMPUS DESIGN PRINCIPLES 9

2.1. Sustainability and Sustainable Campus 9

2.2. Sustainable Campus Design Principles 15

2.3. Sustainable Campus Design Measures 20

2.4. Summary and Evaluation 23

CHAPTER 3. EFFICIENT WATER MANAGEMENT FOR A USTAINABLE CAMPUS 24

3.1. Efficient Water Management Approaches 24

3.2. Stormwater and Rainwater Harvesting Techniques 28

3.2.1. GreenRoofs 29

3.2.2. Rainwater and Stormwater Storage Techniques 32

3.2.3. Sustainable Stormwater Drainage Systems 34

3.2.4. Stormwater Basins 38

3.2.5. Pervious Paving 47

3.3. Green Street 50

3.3.1. Green Street Application Types 50

3.4. Green Parking 56

3.5. Efficient Landscape and Irrigation 59
3.6. Grey Water Systems 60
3.7. Stormwater Management Techniques Application Areas 61
3.8. Limitations 63
3.9. Summary and Evaluation 64

CHAPTER 4. SUSTAINABLE CAMPUS WATER MANAGEMENT APPLICATIONS.. 65
4.1. University of North Carolina, Chapell Hill 72
4.2. University of Wisconsin-Milwaukee 79
4.3. Portland State University 84
4.4. Georgia Institute of Technology 89
4.5. University of Arizona 93
4.6. King Abdullah University of Science and Technology (KAUST) 97
4.7. Demonstration Projects of University Campuses 100
4.7.1. Massachusetts Institute of Technology "The Stata Center Rainwater System" 100
4.7.2. Villanova University(Pennsylvania) "Stormwater Research and Demonstration Park" 102
4.7.3. University of Arizona "Sonoran Research Laboratory" 103
4.8. Sustainable Campus Developments in Turkey 104
4.9. Summary and Evaluation 108

CHAPTER 5. THE CASE OF IZMIR INSTITUTE OF TECHNOLOGY CAMPUS 109
5.1. Site Analysis of IYTE Campus 109
5.1.1. Topography and Slope 111
5.1.2. Geology 116
5.1.3. Vegetative Cover 118
5.1.4. Climate 123
5.1.5. Watershed Context and Water Resources 124
5.1.6. Infrastructure 135
5.1.7. Campus Development History and Master Plan 148
5.2. Evaluation 152

5.3. Best Management Practices (BMPs) for IYTE Campus 160
5.4. Summary.....175

CHAPTER 6. CONCLUSION.....176

REFERENCES 180

APPENDICIES
APPENDIX A. DETAIL OF PROPOSED BMP(s) FOR IYTE CAMPUS.....189
APPENDIX B. LEED-ND (2009) RATING SYSTEM 193

LIST OF FIGURES

Figure **Page**

Figure 2.1. Sustainable System 10
Figure 2.2. Framework of Campus Sustainability 11
Figure 2.3. Integrated Management of the Urban Water Cycle 13
Figure 2.4. A System Approach to Landscape 14
Figure 3.1. Extensive Roof 30
Figure 3.2. Extensive Roof Section 30
Figure 3.3. Extensive Roof/ Vancouver City Library 31
Figure 3.4. Extensive Roof/ University of Florida 31
Figure 3.5. Intensive Green Roof Detail 31
Figure 3.6. Intensive Green Roof/ LDS Conference Center, Salt Lake City, UT 32
Figure 3.7. Intensive Green Roof/ Kingsbury, Chicago, IL 32
Figure 3.8. Water RetentionTank 32
Figure 3.9. Rainwater Conveyance 33
Figure 3.10. Rainwater Conveyance 33
Figure 3.11. Barrel 33
Figure 3.12. Cistern/University of Florida 33
Figure 3.13. Barrel 34
Figure 3.14. Bio (Dry) Swale Plan View 35
Figure 3.15. Bio (Dry) Swale Detail 35
Figure 3.16. Bio (Dry) Swale Section 36
Figure 3.17. Bio (Dry) Swale 36
Figure 3.18. Vegetated (Wet) Swale Plan 37
Figure 3.19. Vegetated (Wet) Swale at Costsco Parking Lot 37
Figure 3.20. Vegetated (Wet) Swale 37
Figure 3.21. Bioretention Area Plan View 38
Figure 3.22. Bioretention/ University of Florida 39
Figure 3.23. Aerial View of Dell Pond / University of Virginia 40
Figure 3.24. Dell Pond / University of Virginia 41
Figure 3.25. Dry Pond Plan and Elevation 41
Figure 3.26. Wet Pond Plan 41

Figure 3.27. Constructed Wetland Plan 42
Figure 3.28. Filter Strip Plan and Profile 43
Figure 3.29. Filter Basin 44
Figure 3.30. Infiltration Trench 44
Figure 3.31. Planter Box Detail 45
Figure 3.32. Contained Planter Box Section 46
Figure 3.33. Contained Planter Box 46
Figure 3.34. Infiltration Planter Box 46
Figure 3.35. Flow Through Planter Box 47
Figure 3.36. Surface Permeability 48
Figure 3.37. Materials of Gravelpave 48
Figure 3.38. Application of Gravelpave to Surface 48
Figure 3.39. Materials of Grasspave 49
Figure 3.40. Application of Grasspave 49
Figure 3.41. Materials of Slopetame 49
Figure 3.42. Application of Slopetame 49
Figure 3.43. Part of a Local Stormwater System 50
Figure 3.44. Ne Fremont Green Street, Portland 51
Figure 3.45. Plan of Curb Extension 51
Figure 3.46. Siskiyu Street, Portland 52
Figure 3.47. Portland 52
Figure 3.48. Plan of Curbbulb-outs 52
Figure 3.49. Portland 53
Figure 3.50. Plan of Sidewalk Planters 53
Figure 3.51. Well or Tree Box Filter 54
Figure 3.52. Inlet 55
Figure 3.53. Inlet 55
Figure 3.54. Inlet 55
Figure 3.55. Inlet Design Plan View 55
Figure 3.56. Green Parking 56
Figure 3.57. Gently Sloping Grassed Area on Parking Lot 57
Figure 3.58. Design Concept for Bio-retention Swale 58
Figure 3.59. Landscape Street Edge 58
Figure 3.60. Shade Within the Lot 58

Figure 3.61. Bio-retention Area 59
Figure 3.62. Permeable Surface 59
Figure 3.63. Pervious Paving 59
Figure 3.64. Grey Water System 61
Figure 3.65. Semi-detached House Application 62
Figure 3.66. Row House Application 62
Figure 3.67. Mix Use Area Application 63
Figure 4.1. World Map of Köppen Climate Classification 66
Figure 4.2. Climatic Zones of the North U.S.A 67
Figure 4.3. University of North Carolina Site Plan 72
Figure 4.4. Proposed All Best Management Practice Locations on UNC Hill Campus 74
Figure 4.5. Global Education Center Green Roof 75
Figure 4.6. Bell Tower Complex 75
Figure 4.7. Friday Center Lot 76
Figure 4.8. Rams Head Center 76
Figure 4.9. Rams Head Center Plan 77
Figure 4.10. Rams Head Center 77
Figure 4.11. Rams Head Center Storage System Construction 77
Figure 4.12. Rams Head Center Rainwater Drainage from Roof 77
Figure 4.13. Carmichael Field 78
Figure 4.14. Carmichael Field 78
Figure 4.15. Sandburg Residence Hall Roof (Present) 79
Figure 4.16. Sandburg Residence Hall Green Roof (Future) 79
Figure 4.17. Golda Meir Library 80
Figure 4.18. Golda Meir Library Green Roof 80
Figure 4.19. UWM Union (Present) 80
Figure 4.20. UWM Union Green Roof (Future) 80
Figure 4.21. Union Entry (Present) 80
Figure 4.22. Union Entry Green Roof (Future) 80
Figure 4.23. Merrill Hall Downspout 81
Figure 4.24. Proposed Rain Garden Connected with Downspout 81
Figure 4.25. Chapman Hall Proposed Rain Garden 81
Figure 4.26. Curtin Hall Proposed Rain Garden 81

Figure 4.27. Proposed Stormwater Planter 82
Figure 4.28. Proposed Stormwater Pocket Wetland 82
Figure 4.29. Spiral Garden Basin 82
Figure 4.30. Spiral Garden Basin 82
Figure 4.31. Pavilion Gateway Demonstration Project 83
Figure 4.32. Connected Water Ways 84
Figure 4.33. Epler Hall Stormwater Harvesting System 85
Figure 4.34. Conveyance 85
Figure 4.35. Epler Hall Stormwater Harvesting System 86
Figure 4.36. Planter Box 86
Figure 4.37. Project Site Plan 87
Figure 4.38. Planter Boxes 87
Figure 4.39. Planter Boxes 87
Figure 4.40. Ornamental Trench Grates 88
Figure 4.41. Curb-Cut Openings to Planter Boxes 88
Figure 4.42. Green Roof 88
Figure 4.43. Map of Eco-Commons 90
Figure 4.44. Drainage Pattern by the Grid of Street Corridors 90
Figure 4.45. Concept Plan of Eco-Commons from State Street 90
Figure 4.46. Georgia Tech. Eco-Commons Project 91
Figure 4.47. Eco-Commons Phase I 92
Figure 4.48. Eco-Commons Phase I Storage Flow Plan 92
Figure 4.49. Eco-Commons Detail 93
Figure 4.50. Rainwater Drainage from Downspouts 94
Figure 4.51. Curb-cuts for Surface Runoff Drainage 95
Figure 4.52. Parking Lot Surface Drainage Through Vegetated Area 95
Figure 4.53. Tree Well on Sidewalk 96
Figure 4.54. Tree Well Section 96
Figure 4.55. Site Plan of KAUST 97
Figure 4.56. Academic Buildings of KAUST 98
Figure 4.57. Comprehensive Irrigation Plan of KAUST 99
Figure 4.58. Irrigation Zones of KAUST 99
Figure 4.59. MIT's Stata Center Rainwater System 101
Figure 4.60. Stata Center 101

Figure 4.61. Stata Center Wetland 101
Figure 4.62. Villanova University Stormwater Research & Demonstration Park 102
Figure 4.63. Stormwater Wetland 103
Figure 4.64. Bio-infiltration Traffic Island 103
Figure 4.65. Porous Concrete Demonstration Site 103
Figure 4.66. Infiltration Trench 103
Figure 4.67. Sonoran Research Laboratory 104
Figure 4.68. Sonoran Research Laboratory 104
Figure 4.69. Sonoran Research Laboratory Pond 104
Figure 4.70. Rainfall Quantity between the years 1971 to 2000 in Turkey 105
Figure 4.71. Sabancı University Pond Area 106
Figure 4.72. Sabancı University Pond Area 106
Figure 4.73. Future Site Plan of Özyeğin University 107
Figure 4.74. Future Academic Buildings 108
Figure 4.75. View from Plaza 108
Figure 5.1. Location of the IYTE Campus 110
Figure 5.2. Aerial View of IYTE Campus Area Boundries 110
Figure 5.3. Aerial View of IYTE Campus Built-Up Area 110
Figure 5.4. IYTE Campus Slope Analysis 112
Figure 5.5. IYTE Campus Elevation Analysis 113
Figure 5.6. IYTE Campus Profile Locations 114
Figure 5.7. IYTE Campus Profile Graphs 115
Figure 5.8. Geophysical Measurement Points 116
Figure 5.9. Iyte Campus Geological Analysis 117
Figure 5.10. Vegetative Colour in Winter 119
Figure 5.11. Vegetative Colour in Summer 119
Figure 5.12. Vegetative Cover of IYTE Campus 120
Figure 5.13. Existing Tree Coverage of IYTE Campus 121
Figure 5.14. Cultivated Landscape 122
Figure 5.15. Cultivated Landscape 122
Figure 5.16. Cultivated Landscape 122
Figure 5.17. Cultivated Landscape 122
Figure 5.18. Cultivated Landscape 122
Figure 5.19. Cultivated Landscape 122

Figure 5.20. IYTE Campus Temperature Variation 123
Figure 5.21. IYTE Campus Moisture Variation 123
Figure 5.22. IYTE Campus Wind Speed Variation 124
Figure 5.23. Stream on Campus 125
Figure 5.24. Waterfall on Campus 126
Figure 5.25. Waterfall on Campus 126
Figure 5.26. Natural Pond on Campus 127
Figure 5.27. Manmade Pond on Campus 127
Figure 5.28. IYTE Campus Watershed Context Analysis 128
Figure 5.29. IYTE Campus Built-Up Area Drainage Analysis 129
Figure 5.30. Locations of Well 1 and Well 4 on Campus 130
Figure 5.31. IYTE Campus Well Levels 131
Figure 5.32. Weekly Water Levels at Wells According to Rainfall 131
Figure 5.33. Daily Water Levels at Wells according to Rainfall 132
Figure 5.34. Constructed Pond on Campus 132
Figure 5.35. Constructed Pond on Campus Figure 133
Figure 5.36. Constructed Pond on Campus 133
Figure 5.37. Water Consumption of IYTE Campus 133
Figure 5.38. Water Consumption of IYTE Campus 134
Figure 5.39. Water Consumption Cost of IYTE Campus 134
Figure 5.40. Open Concrete Channel 135
Figure 5.41. Gutter and Channelized Stream 135
Figure 5.42. Gutter 135
Figure 5.43. Gutter 136
Figure 5.44. Concrete Channel 136
Figure 5.45. Channel to Gutter 136
Figure 5.46. Conveyance 137
Figure 5.47. Conveyance 137
Figure 5.48. Open Concrete Channel 137
Figure 5.49. Open Concrete Channel 137
Figure 5.50. IYTE Campus Infrastructure Scheme 138
Figure 5.51. Channelized River on North Basin 139
Figure 5.52. Channelized River on North Basin 139
Figure 5.53. Channelized River on South Basin 139

Figure 5.54. Disconnected Downspout at Faculty of Architecture 140
Figure 5.55. Disconnected Downspout at Faculty of Architecture 140
Figure 5.56. Disconnected Downspout at Arge Building 140
Figure 5.57. Disconnected Downspout at Computer Engineering Building 140
Figure 5.58. Connected Downspouts 141
Figure 5.59. Connected Downspouts 141
Figure 5.60. Stone Surface Puddles 141
Figure 5.61. Marble Surface Puddles 141
Figure 5.62. Stone Surface Puddles 142
Figure 5.63. Asphalt Surface Puddles 142
Figure 5.64. Asphalt Surface Puddles 142
Figure 5.65. Stone Surface Puddles 142
Figure 5.66. Asphalt Surface Puddles 142
Figure 5.67. Asphalt Surface Puddles 142
Figure 5.68. Asphalt Surface Puddles 143
Figure 5.69. Asphalt Surface Puddles 143
Figure 5.70. Asphalt Surface Puddles 143
Figure 5.71. Asphalt Surface Puddles 143
Figure 5.72. Asphalt Surface Puddles 143
Figure 5.73. Erosion that Occurs at Faculty of Science 144
Figure 5.74. Erosion that Occurs at Faculty of Architecture 144
Figure 5.75. Leaky Surfaces 144
Figure 5.76. Leaky Surfaces 144
Figure 5.77. Concrete Drainage Way 145
Figure 5.78. Concrete Drainage Way 145
Figure 5.79. IYTE Campus Infrastructure Scheme Problematic Areas 146
Figure 5.80. Water Tanks on Campus 147
Figure 5.81. Treated Water 147
Figure 5.82. Drip Irrigation System 147
Figure 5.83. Campus Development Process 148
Figure 5.84. IYTE Campus Initial Master Plan 149
Figure 5.85. IYTE Campus Initial Master Plan 150
Figure 5.86. IYTE Campus Existing and Proposed Projects 151
Figure 5.87. Curb-Cuts Application 155

Figure 5.88. Curb-Cuts Application 155
Figure 5.89. Pervious Slape at Cafeteria..... 155
Figure 5.90. Pervious Slape at Faculty of Science 155
Figure 5.91. Existing Condition of IYTE Campus 157
Figure 5.92. Future Condition of IYTE Campus 158
Figure 5.93. Proposed BMP Scheme of IYTE Campus 163
Figure 5.94. Present Condition 165
Figure 5.95. Future Condition..... 165
Figure 5.96. Present Condition 165
Figure 5.97. Future Condition..... 165
Figure 5.98. Present Condition 166
Figure 5.99. Future Condition..... 166
Figure 5.100. Swale on-contour..... 166
Figure 5.101. Present Condition 167
Figure 5.102. Future Condition..... 167
Figure 5.103. Proposed Detention Basin Area 168
Figure 5.104. Proposed Detention Basin Area 168
Figure 5.105. Proposed Detention Basin Area 168
Figure 5.106. Proposed Detention Basin Area 168
Figure 5.107. Proposed Detention Basin Area 168
Figure 5.108. Present Condition 169
Figure 5.109. Future Condition..... 169
Figure 5.110. Present Condition 169
Figure 5.111. Future Condition..... 169
Figure 5.112. Present Condition 170
Figure 5.113. Future Condition..... 170
Figure 5.114. Proposed Underground Storage..... 170
Figure 5.115. Proposed Underground Storage..... 170
Figure 5.116. Present Condition 171
Figure 5.117. Future Condition..... 171
Figure 5.118. Present Condition 172
Figure 5.119. Future Condition..... 172
Figure 5.120. Present Condition 172
Figure 5.121. Future Condition..... 172

Figure 5.122. Present Condition 173
Figure 5.123. Future Condition 173
Figure 5.124 Proposed Curb-Extension on Campus 173
Figure 5.125. Future Condition 173
Figure 5.126. Daylighted Part of the Stream 174

LIST OF TABLES

Table **Page**

Table 2.1. Sustainability Assessments Developed for University Campuses..... 12
Table 2.2. Sustainable Campus Examples..... 18
Table 2.3. Criterion in Selecting a USGBC Sustainable Design Measures..... 21
Table 3.1. Alternative Water Resources..... 27
Table 3.2. Comparison of Extensive and Intensive Green Roofs..... 30
Table 4.1. Climatic Zones of the Sustainable University Campuses..... 67
Table 4.2. Sustainable Universities Water Management Applications..... 68
Table 5.1. Comparison of Impervious/Pervious Areas of IYTE Campus..... 154
Table 5.2. SWOT (Strenghts,Weaknesses,Opportunities and Threats) Analysis..... 159
Table 5.3. Structural and Non-structural BMPs for IYTE Campus..... 162

CHAPTER 1

INTRODUCTION

1.1. Background

Environmental issues such as climate change, greenhouse effects, water, air and soil pollutions are the important issues to be taken into consideration in these days. Therefore, environmental degradation occurs as a result of human behaviors of consumption and production in daily life but the non-renewable asset of water is consumed unconsciously. Water resources play an important role in the world and water is necessary to be survive. Increasing the level of global warming makes the water issue essential because it causes draught and flood risk. With flood, vast amount of water flow and damages the environment. However, the surface runoff can be turned into an opportunity to reduce the consumption of potable water. Especially, this becomes an important issue for arid and semi-arid regions. Therefore, rainwater or stormwater are the amenities to be evaluated as an alternative water resource instead of potable water for both indoor and outdoor services. However, insufficient plan and urban design strategies or unconscious implementations create unsustainable environments and consume of nonrenewable assets.

Educational institutions especially universities play an important role for sustainable development. They have become a role model for societies to supply the economic, social and ecologic needs with their studies and investigations. Also, they should have a role of identifying the ecological issues and sustainable developments both for the citizens and all society. Therefore, the climatic and sustainability issues can be a research problem for the universities and the campus area should become a laboratory for their practices. Generally, awareness of environmental issues is adopted to their educational methods. Most of the universities have taken this role all over the world; also the students have experienced this process within the studies on campuses so they will have a chance to practice them in daily life. The university campuses are large open areas and include most of functions therefore; the campus development involves planning a physical environment that respond to environmental assets.

Recently, “Green Campus” concept has been developed and most of the university campuses adopt green design strategies to their campus design to reduce negative impacts for environment.

On the other hand, green infrastructure has started to replace the traditional piped infrastructure systems to be more sustainable of water resources. In the world, this system has been widen and the application scale varies from building to neighborhood unit scale. Generally, university campuses have applied green infrastructure techniques to their new developments or retrofit to existing system. However, most of them have become aware of cost effectiveness of the sustainable system and adaptation to existing system with efficient landscape design strategies.

1.2. Problem Definition

Sustainability concept arises with the climate change and increasing environmental problems. Around the world, most of the campus master plans and designs increasingly adopt sustainability approach to protect the vital sources and to prevent the environmental degradation. The water management is a significant issue because of global warming and scarcity of water resources. Water is a necessity for life. However, the scarcity of water is increasing gradually and the world is running out of potable water. The growth of the cities has affected the urban hydrology, also, reduced the permeable ground surface areas. Additionally, groundwater level is lowered. Around the world, most of the universities are aware of their effects to environment because of the human activities, so they develop strategies to reduce the potable water use and capture rainwater both in arid and semi-arid regions. Besides, they have developed Stormwater Management Plan, Landscape Master Plan or Water Resources Master Plan to implement green infrastructure techniques and protect environmental assets.

Traditional piped system causes several problems such as flood, degradation of water quality, increase of impermeability and ineffective cost. The proper green infrastructure techniques will prevent these problems however limitations determine the proper technique for each site because the soil type, geological features, slope, landscape and climatic conditions of the site affect the practices of the techniques. Therefore, efficient landscape design supports to adopt these techniques for both

existing and future developments because landscape elements and their types will affect the water consumption.

Firstly, this study is going to show what the university administration develops as a vision for environmental assets especially for water resources on campus; then, which strategies are developed for case area of IYTE Campus. Later, study is going to schematically specify how to capture and reuse the stormwater with green infrastructure techniques cost effectively according to the site limitations on campus to reduce the consumption of the clean water and protection of the water quality. However, rainwater is a free source so it can be reused for non-potable uses; actually it can be used as a potable water resource after a good treatment process. Besides, the other alternative water resource strategies is going to be specified for campus such as reuse of greywater and air-conditioner condensate.

1.3. Aim and Objectives

This thesis is concerned with sustainable approach to water management for a sustainable campus with an aim of protecting the quality and quantity of water resources by using proper green infrastructure techniques with efficient landscape design, instead of traditional piped system, also, capturing stormwater on the site, reusing treated captured water for irrigation and other outdoor uses and reducing the consumption of clean water are the other goals of the study.

This thesis aims to answer the research question of “How to guide future campus growth and development in a more sustainable manner with regards to water resources” with the sub-questions of;

“What are the approaches for water management on campus in the world?”

“Which green infrastructure techniques are applied on campus both on campuswide and in detail?”

Therefore, the study aims to examine the campus with green infrastructure techniques while eliminating the inconveniences of existing conditions.

1.4. Methodology

The methods used in this study have been established to observe, evaluate, and assess sustainable stormwater management initiatives on campus landscapes for sustainable development through the use of literature, internet searches and academic journal articles. A case study approach has been adopted and conducted through site survey and data collection, personal interviews, and assessment of campus development plans. Lastly, the evaluation of SWOT analysis and development of Stormwater Management Scheme have been presented as a result.

1.4.1. Literature Survey and Review

Firstly wide literature survey has been conducted on concepts of sustainability and sustainable campus, evaluation of sustainable campus principles with an emphasis on water management, green infrastructure techniques and their applications, sustainable campus examples around the world, case studies of campus stormwater management implementations in detail, green campus approaches in Turkey have been carried out. Journal articles and books, academic research reports and dissertations, university internet sites on sustainability and digital libraries are utilized to accomplish the literature review. The literature and case studies review were found to be useful in providing a methodology for analysis.

1.4.2. Case Study

In the case part of the thesis, firstly, a case area is determined after the review of campus projects in the world especially similar characteristic sites have been taken as a guide. Therefore, IYTE Campus has been chosen as a study area. The sustainability issue is essential for IYTE Campus because of its non-urban site, wide built-up area and being a part of an eco-system. Therefore, sustainability principles should be taken as a guide to prevent the high construction and imperviousness ratio. There are various streams and riverbeds, therefore it is important to provide the hydrological balance on campus with protecting the quality and quantity of water reservoirs and the habitat.

Stormwater that is drained to streams with open or closed channels cause water pollution because of the washed away pollutants. For that reason, this study has matters for the agricultural lands close to campus.

On the other hand, Gülbahçe Village has been well known for the potable water resources and they have supplied their water from groundwater reservoirs, but campus is dependent on Urla to supply water so green infrastructure elements will help to develop campus landscape and be compatible with nature, and provide to independency for potable water.

After selection of the case area, site analysis that consists data collection and personal interviews, evaluation of analysis and plan development parts constitute the case study of the thesis.

Site survey/analysis: The analysis of the IYTE campus was performed by evaluating both the natural and built systems. In terms of analysis of natural site features, the following categories have been investigated; slope and elevation, geology and soil, vegetative cover, climate, watershed and water resources. The analysis of built systems includes inventory of existing stormwater drainage system and the problem areas with the existing stormwater drainage system, and an assessment of campus master plan. A site tour was organized to observe various existing drainage system throughout campus and multiple site visits were performed to observe campus conditions during storm events. A review of existing campus stormwater conditions, including site-specific locations of problems and opportunities, and documentation of areas of concern (localized flooding, water quality issues, etc.). Drainage utility infrastructure needs were analyzed for existing and planned future development conditions. The site analysis has been performed by use of the computer program of GIS technique. Aerial photo has been used as a base of analysis with GIS technique.

Data collection: It consists of three major components: hydrological data, rainfall data, and water consumption on IYTE campus.

a. Hydrological data: Hydrological data of IYTE Campus is essential for the study to identify the both surface and ground water capacities and potentials but it can not be provided. Therefore, research project results on campus by Prof. Dr. Gökmen Tayfur were evaluated. Also, water consumption data on campus were gathered to emphasize the importance of potable water.

b. Rainfall data: An evaluation of the rainfall data at IYTE for the purpose of identifying the precipitation patterns that contribute to stormwater runoff, groundwater

recharge, and pollutant discharge to the river and the Gülbahçe Golf is necessary. A detailed analysis of the amount of runoff and associated pollutant loads, on an annual basis, from the different drainage areas and land uses within the campus under existing conditions has been done by Prof. Dr. Gökmen Tayfur so research results were evaluated.

c. Meteorological data: Meteorological data on IYTE campus or surroundings including average rain quantity, air temperature (ºC), wind speed (m/s) and relative humidity (%) has been requested from the Turkish State Meteorological Service but there are not any specific data for IYTE Campus so research project results on campus by Prof. Dr. Gökmen Tayfur were used.

d. Geological data: Necessary geological data for IYTE Campus that is mostly important to determine the water storage possibility and capacity in ground can not be provided. Therefore, campus research project results by Assoc. Prof. Dr. Alper Baba were evaluated.

Personal interviews: Additional information about drainage utility infrastructure, potable water and sanitary sewer network were gathered by the interviews with campus staff (Constructions Office). Campus landscaping information was gathered through the interview with the campus landscape architect. Also, interviews with people who were involved within the campus development process have been conducted and University archive was examined for Campus development history.

Additionally, research was conducted on campus development through review of aerial photography and photos from the mid 1990's, when construction was started to the present, were used to interpret and track the evolution of campus development as well as changes and interventions in the natural landscape. The review of aerial photos and superimposition of the built concrete channels with the aerial photos revealed streams that over time have been channelized and/or diverted. This analysis informs the understanding of current conditions as well as the plan for regenerative and restorative practices in stormwater and landscape management on the campus.

Evaluation: An overall evaluation of opportunities and constraints on the Campus for the analysis that are conducted for water management and applicability of green infrastructure techniques and especially, landscape with consideration of existing trees, utilities, and other potential conflicts, was developed to identify opportunities to integrate stormwater measures and retrofit the existing campus. This analysis was intended to identify areas available to integrate landscape-based stormwater measures.

A SWOT (strengths–weaknesses–opportunities–threats) analysis was performed to understand further the campus's problems and what is causing them, as well as to understand its potentials and qualities that will be the starting point for developing the sustainable stormwater management strategies. Comparison of imperviousness rate of existing and future "build-out" conditions were also investigated to determine the impact of the changes that will be incorporated by Campus Plan which identifies the new buildings to be constructed and the physical changes that the campus will experience in the years to come.

Plan Development: The results of these investigations and assessments are used to develop strategies for sustainable Stormwater Management Plan and locate logical and effective design opportunities for rainwater catchment throughout the campus. The strategies and plan development were grounded also on the U.S. Green Building Council's (USGBC) LEED for Neighborhood Development (LEED-ND) guidelines in order to accomplish sustainability of water resources on campus. LEED-ND offers a means to integrate principles of environmental sustainability into new, large-scale developments such as campus expansion projects through a holistic approach to neighborhood planning. In parallel with this, locations of the Best Management Practices (BMPs) are specified campus wide and a conceptual Sustainable Stormwater Management Scheme has been developed with locations of BMPs.

1.5. Organization

After a brief introduction, Chapter One specifies the concepts of sustainability and sustainable campus, then sustainable system context and sustainable campus framework are mentioned.

After Chapter Two gives the concept identifications and explanations, then, the sustainable campus design principles with a focus on sustainable water management and the green design measurements developed by some countries are mentioned and the one which is usually preferred for campus expansion project is emphasized.

Later, Chapter Four explains the techniques about the water management around the world and best management practices (BMPs) from the university campuses in the world are mentioned.

Then, Chapter Five discusses the water management at IYTE campus. The Campus is analyzed for the existing condition then evaluated and developed strategies according to the green infrastructure techniques for future conditions.

Lastly, in Conclusion, after reviewing all the findings from the study, the importance of water resources is emphasized and recommendations about water management are given for further researches.

CHAPTER 2

CAMPUS SUSTAINABILITY AND SUSTAINABLE CAMPUS DESIGN PRINCIPLES

In this chapter, concept of sustainability and sustainable campus are introduced; the relation of sustainability concept with campus planning and in which ways this concept affects the university campuses is discussed. Then, sustainable campus design principles are defined and the sustainable campus examples are expressed briefly.

2.1. Sustainability and Sustainable Campus

Sustainability is a general term derived from the word "sustainable" which means "capable of being maintained at a certain rate or level" (Oxford English Dictionary, 2009). Also, sustainability means "…a dynamic balance among three mutually interdependent elements: (1) protection and enhancement of natural ecosystems and resources; (2) economic productivity; and (3) provision of social infrastructure such as jobs, housing, education, medical care and cultural opportunities" (Bell and Morse, 1999). Sustainability constitutes a balance between the environment and human. The relations between the human system and eco-system help to protect the natural resources and prevent to reduce them. This can be achieved with human behaviors and strategies. As we see in the Figure 2.1, the relation between the ecosystem and the human system can be provided with indoor environment and air quality, transportation management, water management, energy management, waste management, land management and bio-diversity management and interactions between them. The thesis will briefly explain water management for sustainable campus. The international usage of the term 'sustainability' was first seen in the **World Charter for Nature**, an organization of International Union for the Conservation of Nature and Natural Resources (Yazar, 2006).

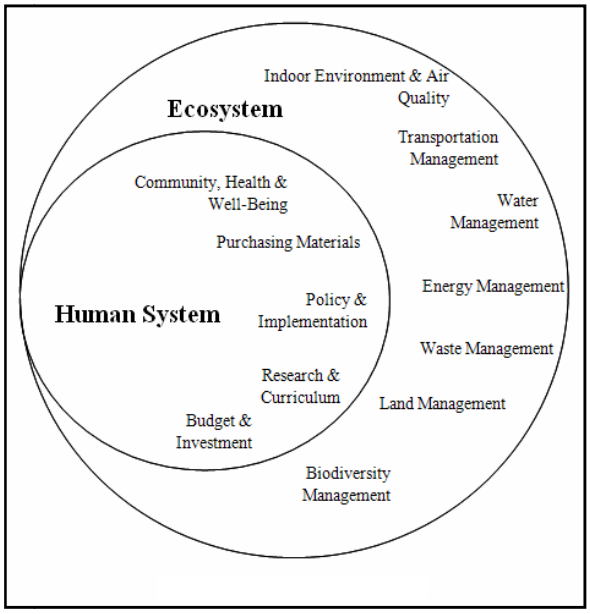


Figure 2.1. Sustainable System
(Source: Mat et al., 2009)

Universities have several activities and complex operations with significant environmental effects so sustainability concept arise with them. As universities became larger and more complex, the term campus came to represent. Campus is a settlement that provide to feel safe to students, staff and visitors, encourage participation and enhances the social interaction (Neuman, 2003). Campus sustainability has become an issue of global concern and the Stockholm Declaration of 1972 was the first to make reference to sustainability in higher education and has recognized the interdependency between humanity and the environment and suggest several ways of achieving environmental sustainability (UNESCO, 1972, seen: Mat et al., 2009). Sustainability issues should be integrated within the main functions of university because the universities are regarded as a small city due to their large area, high population and various complex activities taking place in campuses, have direct and indirect effects on environment. Universities daily operations such as consumption, waste management, use of water and energy should be evaluated according to the sustainability assets (Ciegis and Gineitiene, 2006). Firstly, as a university promotes sustainability approach for its campus, they should adopt three strategies; Environmental Management System (EMS) Implementation, public participation and social responsibility, sustainability teaching and research. Each strategy has initiatives to achieve the sustainability (Figure 2.2).

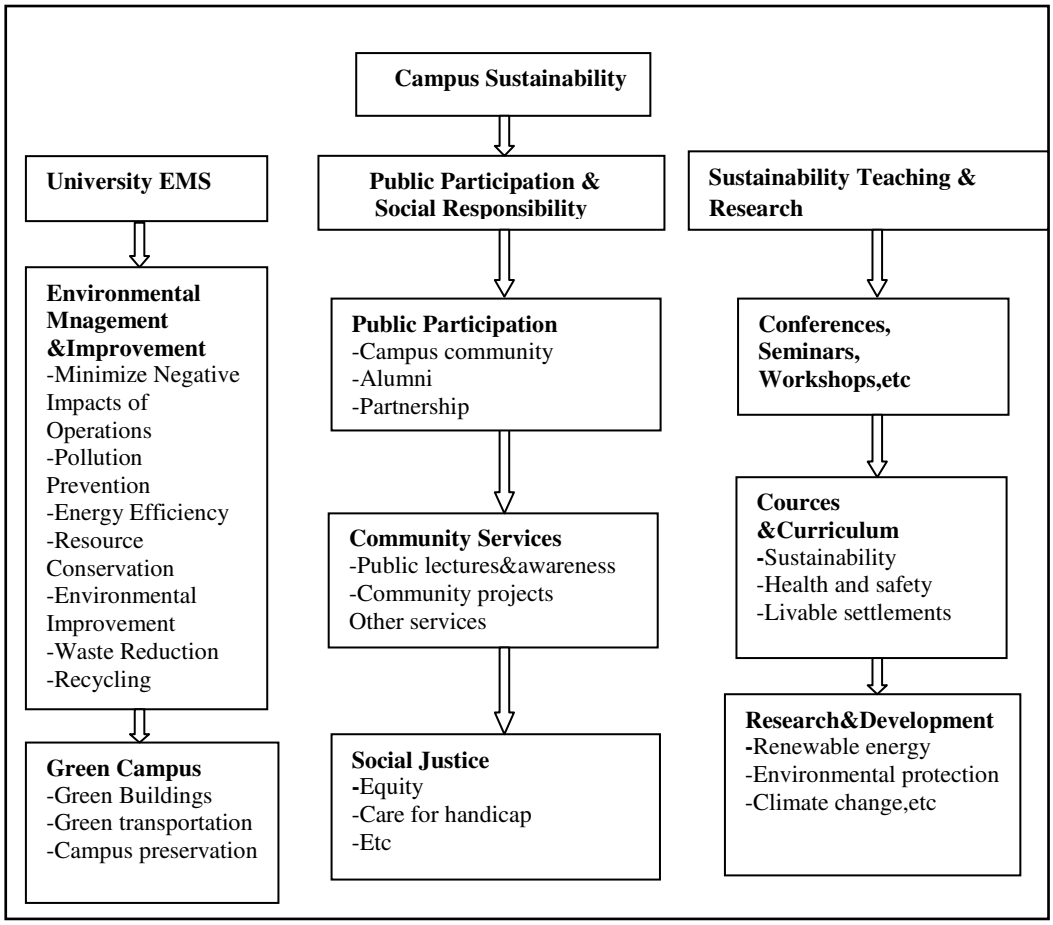


Figure 2.2. Framework of Campus Sustainability
(Source: Alshuwaikhat and Abubakar, 2008, p.1780)

Also, four international organizations which are International Association of Universities, University Leaders for a Sustainable Future, Copernicus-Campus and UNESCO try to adopt the universities to support sustainable development (Mat et al., 2009). Besides them, some sustainable assessments are developed to encourage the sustainability principles for university campuses. These assessments are; Blueprint for a sustainable campus, National Wildlife Federation (NWF) Campus Ecology Program, Clean Air Cool Planet, Ecological Footprint, ISO 14001, The Natural Step, Tallois Declaration, ULSF Sustainability Assessment Questionnaire and Campus Sustainability Assessment Framework (Table 2.1). Both of the assessments were formed to generate solutions for the environmental problems, give recommendations for campus operations with best management practices and help to develop sustainability assets for the university campuses.

Table 2.1. Sustainability Assessments developed for University Campuses (Source: Tuna, 2006, p.33)

Assessment	Description	University Examples
Blueprint for a Green Campus	It is developed at a Campus Summit at Yale University in 1994. It gives recommendations for greening campus operations, curricula, and community relations.	University of Colorado at Boulder, The State University of New York at Buffalo, UC Santa Cruz
National Wildlife Federation (NWF) Campus Ecology Program	It offers practical recommendations about starting projects and details best management practices.	Numerous examples of best practices are available on NWF website.
Clean Air Cool Planet	It is based on Kyoto Protocol. It advocates greenhouse gas emission calculations as well as adopting the provision of the protocol.	Tufts University, Massachusetts Institute of Technology
Ecological Footprint	It measures the amount of renewable and non-renewable ecologically productive land area required to support the resource demands and absorb the wastes of a population.	University of Newcastle (Australia), University of Redlands, Oxford Brookes University (UK),
ISO 14001	International Organization for Standardization (ISO) was adapted for campuses as ISO 14001 by US Environmental Protection Agency (USEPA).	Tulane Humboldt State, University of Missouri, Leeds Metropolitan University
The Natural Step	It is founded in Sweden. It is a conceptual framework for addressing environmental problems.	Georgia Institute of Technology, University of Texas at Houston
Tallois Decleration	Twenty universities from all regions of the world publicized their concerns about environmental problems in 1990.	10 campus based actions to reduce environmental degradation.
ULSF Sustainability Assessment Questionnaire	It aims to raise consciousness and encourage debate about what sustainability means for higher education practically and philosophically.	Best practices are available on ULSF website.
Campus Sustainability Assessment Framework (CSAF)	This framework was developed to create a consistent way of measuring socio-economic and ecological sustainability on campuses in 2003. It is the most common sustainability assessment framework used in campuses across the world.	Greening the Ivory Towers Project, Concordia University , University of California Berkeley

Recent researches develop ideas and strategies to answer question of what a sustainable campus is and which role is taken by universities in sustainable development. A sustainable campus is defined by Velazquez et al. as ‘‘A higher educational institution, as a whole or as a part, that addresses, involves and promotes, on a regional or a global level, the minimization of negative environmental, economic, societal, and health effects generated in the use of their resources in order to fulfill its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyles’’(Velazquez et al., 2006, p.

812). Also, Cole defines sustainable campus as ‘‘the one that acts upon its local and global responsibilities to protect and enhance the health and well-being of humans and ecosystems. It actively engages the knowledge of the university community to address the ecological and social challenges that we face now and in the future’’(Alshuwaikhat and Abubakar, 2008, p.1778). Both of the definitions describe the sustainable campus that improves the quality of human life and improve the balance between environmental, societal and economical assets. As we see in (Figure 2.2), this balance also supports sustainable water management system that consists of potable water conservation, waste water minimization and stormwater management which aims to protect the quality and quantity of potable water.

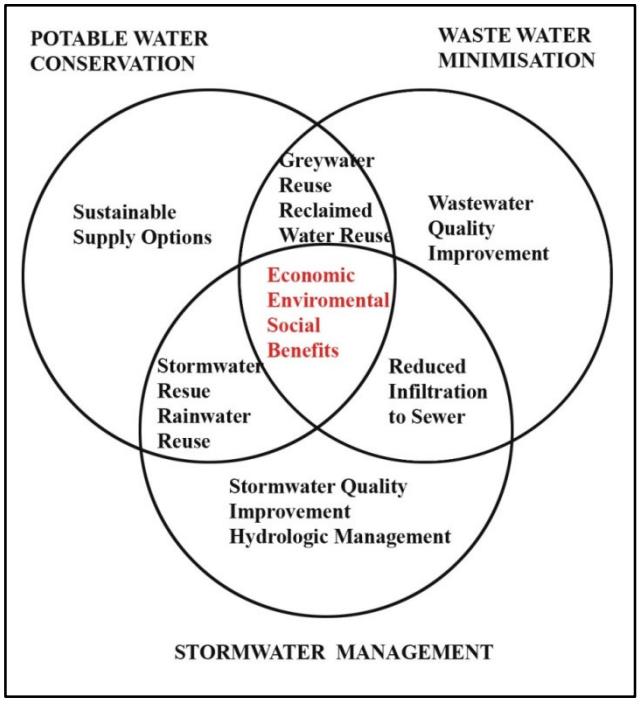


Figure 2.3. Integrated Management of the Urban Water Cycle
(Source: Waterbydesign, 2010)

On the other hand, this sustainable balance affects the landscape design approaches (Figure 2.3). The figure shows the difference between two approaches. These approaches are open unsustainable system which includes non-renewable energy sources, water resources excluding rainwater, pesticides, minimum recycling, use of existing materials and results with stormwater runoff, polluted water and heat energy and closed sustainable system which includes renewable energy, local materials,

recycling of water, minerals and dead plant materials and results with clean water, less waste production and less heat gain.

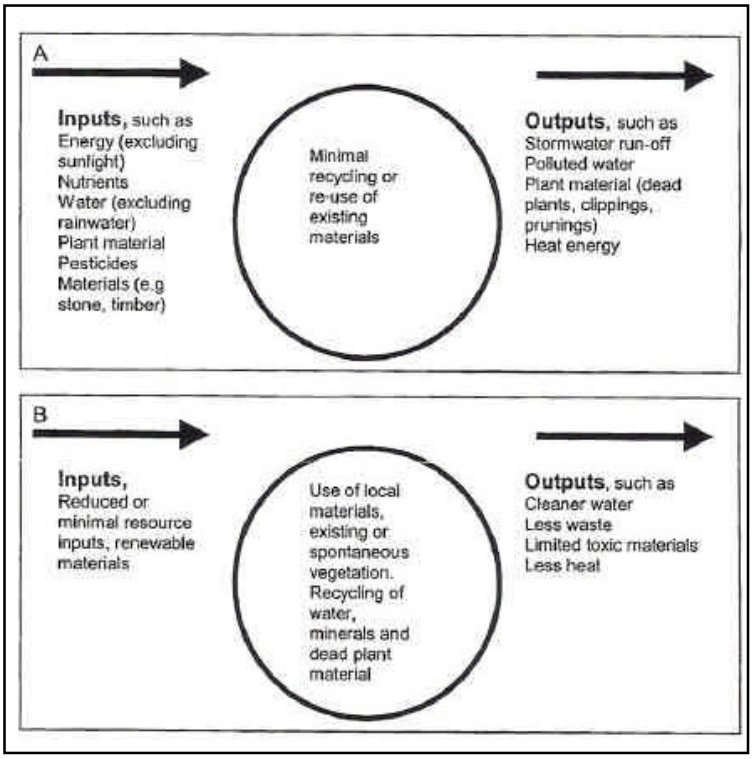


Figure 2.4. A System Approach to Landscape
A: open unsustainable system, B: closed sustainable system
(Source: Benson and Roe, 2000, p.180)

As a result, universities should be a place of laboratory for the researches and applications and also should play a role for a sustainable development of the society. They should promote environmental equilibrium. Education is the best and effective way to achieve sustainable development. Universities are the best places to indicate how we destroyed environment and to understand the responsibilities and sensibilities and have societal responsibility in particular with regard to youth training and public awareness about sustainability (Mikulik and Babina, 2009).

2.2. Sustainable Campus Design Principles

Sustainable design principles recognize the environmental cost of the developments. The essential goal is to protect limited natural resources such as water, land, forests and protection of human health. These principles recommend strategies for future development that can minimize the environmental effects within the categories of site, energy, transportation, water, recycling, landscape and building and material. Selection of a **site** for a location of university campus is an important factor for improving environmental sustainability, because it effects transportation, water, water runoff, utility needs and natural lighting opportunities. So effective campus site selection, orientation of the buildings and use of site after construction are important criteria for whole campus environment. **Energy** is one of the categories to pay attention in design process of a campus. Energy consumption cause most important environmental impact associated with campus operations. Energy sources used by campus operations and the equipment chosen for buildings are important for sustainability. Renewable energy, thermal insulation and high-efficiency lighting systems are solutions to reduce the energy consumption. Besides these categories, **transportation** modes and kind of fuels used at campus should affect the sustainability of campus. For more environmental-friendly transportation, the car use should be reduced and public transportation should be encouraged. Bike roads, biking parks, quality and safe walking roads should be design. High accessibility affects the sustainability, the distance between the buildings should be short to improve the walking and cost effective infrastructure. Also, type of fuel is important for environment. The alternative fuels should be used like bio-diesel and naturalgas. Another category is **water**. When campus plans are done, water resources should be considered because conservation quality and quantity of water resources is an essential factor to become sustainable. University campuses should have Water Management Plan that includes strategies related to stormwater management, greywater systems and potable water. The other category is **recycling**. Recycling the solid waste helps to reduce the negative effects on environment. In the construction of buildings, the kind of material and its effects to the environment should be evaluated for sustainability. Energy efficient and recycled materials should be used. Also, local production plays an important role so local products should be preferred as possible as

(Abubakar and Alshuwaikhat, 2007). Then, **landscape** design is important for sustainability. The type of the plants and trees, pest management approaches, irrigation techniques play an important role. Use landscape for many functions to treat stormwater and reduce heat island. The last one is **building and material**. In this category, orientation of the building, the materials that are used for construction are considered to provide sustainability (Mat et al., 2009).

Environmental problems such as climate change, pollution growth and uncontrolled developments cause water scarcity and degrade water quality. Increasing water scarcity requires efficient water management to meet the future demands. Providing efficient water management which includes stormwater management techniques, greywater systems and protection of the clean water (potable water) are the important issues. University Campuses that adopt sustainability approach to their plans should develop their design principles according to these issues. In world, most of the university campus expansions are developed according to sustainability design principles because as they expand, their construction area enlarge and environmental effects are increasing with high consumption ratios. Increasing environmental quality, social equity and cost affectivity are the visions improved by these universities. Both the new constructed ones like King Abdullah University of Science and Technology (KAUST) or University of California Merced and the developing ones like Oregon University or University of North Carolina adopt sustainability design principles to their plans.

In the (Table 2.2), seven universities are analyzed according to seven categories (Site, transportation, water management, landscape, energy, recycling, building and material) after a detailed literature survey about sustainable campus examples in the world then King Abdullah University of Science and Technology (KAUST), Oregon University, Stanford University, University of North Carolina, University of Nottingham, University of Maryland and Auburn University are chosen to be analyzed. These universities are the best examples for achieving access to proper data, plans, figures and photographs to related issues. They have strategies and applications related to sustainable design principles. Categories are created according to the Leed for Neigborhood Development rating system (Leed-ND) because this rating system is the last one developed in 2009 and proper for campus expansion projects and also will be taken as a reference in the case part of the thesis. Leed-ND rating system is discussed briefly in next section. Both of the categories have design guidelines to adopt

sustainability principles. Universities that are named in the table developed their visions according to the environmental assets and protection of the environmental resources is the aim of their designs. They manage their guidelines according to their site conditions; topography, slope, elevation, geology, climatic features; temperature, wind, rainfall ratio and sun and natural resources; rivers, woodland areas, meadows and fault lines. The climatic zones are important for the design techniques and application efficiency. These seven universities are in different climatic zones so application techniques are changing.

Table 2.2. Sustainable-Campus-Examples

Universities	Site	Transportation	Water Management	Landscape	Energy	Recycling	Building and Material
Oregon University (Eugene, Portland, U.S)	*Design usable outdoor spaces. *Select and position landscape materials to aid in achieving energy efficiency.	*Provide incentives for walking, cycling, busing and ridesharing. *Discourage use of single- occupancy cars. *Instructional core within a six to seven minute walking circle to allow for pedestrial travel.	*Maximize on-site stormwater management. *Rain harvesting systems *Use plant materials and terrain to slow and absorb runoff, filter sediments, andfacilitateinfiltration. *Maximize pervious surfaces to permit water infiltration. *Minimize the need for landscape irrigation. *Usenaturaldrainageways *Make use of gray water and water-saving devices	*Use native or well-adapted species for landscaping *PestManagement approach	*Maximize lighting efficiencies and reduce heat gain, use occupancy sensors for lighting. *Integrate a well-controlled daylighting system with other building systems	*Recycle yardwaste into compost forreuse.	*Orient buildings to make optimal use of site conditions such as solar, airflow,lighting, soil, vegetative, and topographic conditions. *Considerthebuilding envelope design carefully, including glazing selection, window anddoor shading, wall construction, roof color, and building shape. *Use recyclable products and those with recycled material content
Stanford University (Stanford, California, U.S)	*Infilldevelopment that relates well to both natural systems and existing infrastructure. *Maintain and enhance the biodiversity of natural systems *RespondtoStanford'smicroclimatesandnaturalsite conditions	*Consumption of fosil fuel and traffic-related environmentaleffects. *Use electric and hybrid vehicle	Stormwatermanagement: *Use biologically based storm water management *Maximize pervious and vegetated areas of the site ErosionControl: *Prevent soil erosion before, during, and after construction by controlling stormwaterrunoff and wind erosion. *Siltfencing, sediment traps, construction phasing, stabilization of slopes, and maintaining and enhancing vegetation andgroundcover. *Graywater systems	*Minimize the need for irrigation *Select drought tolerant plant species *Use efficient irrigationsystems that utilize technologies such as drip irrigation, moisture sensors, and weather data-based controllers.	*Reduce total building energy consumption and peak electrical demand *Provide Daylighting Integrated with Electric Lighting Controls *Provide Efficient Electric Lighting Systems and Controls *Use Renewable or Other Alternative Energy Sources, photovoltaic panels, solar water heaters, and wind turbines	*Waste Reduction and Recycling Program diverted more than 14,500 tons of materials from landfills	Optimize Building Envelope Thermal Performance *Use Materials with Low Life-Cycle Cost *Use Locally Manufactured Materials
University of North Carolina (Chapel Hill, North Carolina, U.S)			*Green roof system to collect the stormwater. *Underground cisterns hold rainwater to irrigate the intensivegreenroof. *Efficient fixtures and systems to reduce demand for potable water. *Porous Pavement	*All landscapes will be planned withappropriate native and non-invasive species that supportlow maintenance, low water use, and low fertilizer use.	RenewableEnergyOpportunities Photovoltaicpanels *There claimed wate rproject: Provide cooling tower make-up water forthe University‟s chilled water plants and for athletic field irrigation. *Efficient lighting technology: Compact Fluorescent Lamps (CFLs)or Light-EmittingDiodes(LEDs)		LEED Silver Certified buildings

(cont. on next page)

Table 2.2. (cont.)

Universities	Site	Transportation	Water Management	Landscape	Energy	Recycling	Building and Material
University of Maryland (Baltimor, Maryland, U.S)	*Aims the smarth growth of the campus *Low impact development projects	*Carpools are used *Biking programs are developed *Biodiesel fuel is used for public transportation vechicles *Person commute to campus by single car should meet the EPA's green vechicle standard	*Stormwater collection systems; like cistern *Using fixtures that provide less water demand *River restoration projects	*Use proper plant species	*Energy Star Awarded Combined Heat and Power Plant *Higher efficiency lamps are used for lighting *Carbon dioxide monitors are used to ventilate the buildings	*Most of the solid waste is being diverted from landfills *Implementing a recycling program	*Leed Certified Green Buildings *Green roof
Auburn University (Auburn, Alabama, U.S)	*Protect the natural systems of the campus, such as forests,waterways *Stream restoration *Daylight of the creeks *Reduce heat island effect *Compact development	*Alternative transportation modes to reduce energy consumption and greenhouse gas emissions. *Pedestrizations *Encourage biking and public transportation	*Watershed Protection *Stormwater Management *Pervious Paving *Reducing net water consumption	*Planting deciduous trees along the creeks *Better irrigation practices	*Climate responsive building and site design *Reduce automobile dependency *Utilizing vegetetation as a shading function for buildings.	*Have waste reuse and diversion program *Aim to decrease the amount of waste	*Climate responsive buildings *East-West oriented *Installing White or Green roofs *Encourage to construct of Leed Certified Buildings
King Abdullah University of Science and Technology (Thuwal, Saudi Arabia)	*Locate and group the buildings to maximize the benefits of the unique site,macro climate and the ecosystem. *Light-colored paving and shade to reduce heat island effect.	*Shuttle Buses *Reduction of car use *Alternative Fuel Vechicles *Parking locations through out the campus	*Harvested rainwater and store to reuse *Protect the natural ecosystems and recreational facilities. *Reduce potable water consumption: Efficient water fixtures and waterless urinals	*Using native plants	*Energy Efficiency; renewable energy *Solar Towers and Prevailing wind conditions *Two iconic solar towers on the campus to create a pasive pressure difference	*Recycled construction waste *Implement a recycling and composting program	*Local concrete and steel with high levels of recycled content. *Interior furniture systems that contain no volatile organic compounds(VOC). *All the wood was purchased From sustainability managed forests and is Forest Stewardship Councial certified.
University of Nottingham (Nottingham, U.K)		* Encourage sustainable forms of transport *Provide Free Hopper Bus Services *Encourage cycling		*Planting native species *Reduced the use of pesticides *	*Reduce energy consumption and carbon footprint *Renewable energy sources *	*Reduce resource consumption *Encourage the use of recycle products *Several recycling centers and increased the number of on-street recycling bins * Compost of the garden waste	*Construction Eco-Homes *Provide energy efficiency *Constructed with local materials *Storing rainwater and reuse greywater

2.3. Sustainable Campus Design Measures

In the world, sustainable campus design strategies and applications are developed according to some measures. These measures are **Leadership In Energy and Environmental Design (LEED)** in U.S., **Building Research Establishment Environmental Assesstment Program (BREEAM)** in U.K. and **European Eco-Management and Audit Scheme (EMAS)** in Europe and **Campus Sustainability Assessment Framework (CSAF)** in Canada.

In **U.S.**, most of the universities have campus sustainability offices, department of environment and natural resources. The universities use the **Leadership In Energy and Environmental Design (LEED)** criteria for the campus design. LEED is a point base system that is created in 1998 encourages sustainable green building and new development practices. Projects earn Leed points according to their environmental and health performances. Leed evaluate the performances according to five categories which are; Sustainable Site Development, Water Savings, Energy Efficiency, Materials Selection and Indoor Environmental Quality. USGBC offers several programs that can be applied within a university or college campuses. Leed has nine rating systems and three out of nine is proper for campus development projects. These are Leed for New Construction, Leed for Existing Buildings, Portfolio Programs with volume certification and Leed for Neighborhood Development. **LEED for New Construction (LEED-NC) rating system** is a certification system for new building construction on college and university campuses. It challenges the environmental considerations in designing and constructing a building. LEED- NC has been applied successfully on campuses for new academic and administrative buildings, libraries and residence halls. Emory University is an example for the rating system. University's Biomedical Research Building became the first silver level Leed Certified Project in the Southeast United States that has LEED-NC criteria in 2002. On the other hand, Portfolio programs within volume certification are also applied with new construction projects. University of California Merced achieved Leed Certification with the use of portfolio program for their existing buildings and all new construction in 2002. Leed for New Construction and Leed for Existing Building Systems are used for individual buildings. **LEED for Existing Building (LEED-EB)** provides a method for existing buildings to implement sustainable operations and maintenances. University of California Santa Barbara is an

example that uses Leed-EB criteria. **LEED for Neighborhood Development (LEED-ND)** USGBC's newest rating system integrate principles of environmental sustainability into new, large-scale developments such as **campus expansion projects** through a holistic approach to neighborhood planning. System provides integration of environmental considerations into all aspects of design and developments. This rating system is arranged according to some categories and each category has sub-categories. The points are evaluated according to these categories. Green infrastructure and the building is one of the categories in this system. This category evaluate the Building Water Efficiency, Water-Efficient Landscaping, Stormwater Management and Wastewater Management sub-categories. These sub-categories are water related subjects. Green infrastructure and the building category also has another sub-categories. Colombia University, California State University Sacramento and John Hopkins Universities are in process to achieve LEED-ND Certification. Choosing an appropriate program is important for campuses. There are some criterions to determine the best program (Table 2.3) (USGBC, 2009).

Table 2.3. Criterion in Selecting a USGBC Sustainable Design Measures
(Source: Ried, 2008, p.7)

	LEED-NC / LEED-EB	Volume certification	LEED-ND
COMMITMENT			
Strong commitment to green building	✓	✓	✓
Strong commitment to comprehensive/green planning			✓
EXPERIENCE			
Prior experience with green building and comprehensive/ green planning	✓	✓	✓
CAPACITY/ RESOURCES			
Robust management and staffing for green planning and development		✓	✓
EXPERIMENTATION			
Appetite for experimentation in green design	✓	(✓)	
PROJECT TYPE			
Buildings			
New Construction	✓	✓	
Renovation	✓	✓	
Single Building	✓		
Multiple Buildings (Portfolio)		✓	(✓)
Comprehensive Campus Planning / Large-scale Development			
Comprehensive Campus Plan (Urban Design, Infrastructure & Systems, Building Synergies)		(✓)	✓
Residential or Mixed-use Neighborhood	(✓)	✓	✓
Public Private Partnership Projects			✓
√ Recommended (√) May be recommended under certain circumstances			

All of these rating systems are detailed in appendix part of the thesis. USGBC plan to integrate environmental sustainability on campuses through multiple approaches. Many Universities apply the Leed for New Construction and Leed for Existing Building, but lastly Leed for Neighborhood Development rating system developed. New constructed universities adopted Leed Criteria at establish like UC Merced and other universities adopt Leed Criteria in their developing process. In the world, most of the universities adopt Leed Rating Systems. These systems constitute their design standards and make them more sustainable. Victoria University, Stanford University, Maryland University, California University, Georgia University, Arizona University, Texas University, Clemson University, MIT, Florida University, Oregon University, North Carolina University, Santa Clara University are some of the universities that use **LEED Criteria** as a design guideline for a sustainable campus design (Ried, 2008).

In **U.K, BREEAM** is a Building Research Establishment Environmental Assesstment Program that is most widely used for buildings created in 1990. It sets the standard for best practice in sustainable design and has become the de facto measure used to describe a building's environmental performance. Breeam provides people low environmental impact buildings with innovative solutions. Breeam developed assessments in nine categories for sustainable building. These categories are; Energy and Carbondioxide Emission, Water, Materials, Surface Water Run-Off, Waste, Pollution, Health and Wellbeing and Management and Ecology. According to the categories, there is a rating system.The projects get Pass, Good, Very Good, Excellent or Outstanding Degrees and has Breeam Certificate (Breeam, 2009).

In **Europe, EMAS** is an European Eco-Management and Audit Scheme that brings changes in environmental performance (Alshuwaikhat, M. H. , Abubakar, I. ,2007). This is a voluntary environmental system which companies and other public organizations evaluate, manage and improve their environmental performances. EMAS has been operated since 1995. The scheme has environmental indicators and the companies and organizations order their applications according to indicators (Europa, 2010).

In **Canada**, **CSAF** is a Campus Sustainability Assessment Framework that is an environmental measurement system used in Canadian Universities. This Framework divided into two main sections. People Section and Ecosystem Section. People Section considers the social and economic aspects of sustainability, Ecosystem Section

considers environmental aspects of sustainability. These two sections are divided into five sub-sections which include indicators. The CSAF is the largest scale tool of its kind, containing over 170 indicators, but many campuses will not be able to find information on all of the indicators contained in CSAF (Stewart, 2005).

As a result, sustainability concept is arised at university campuses with the increasing urbanization and scattered developments. Countries developed some design measures to provide the sustainability. Leadership In Energy and Environment (LEED), BREEAM, EMAS and CSAF are the best rating systems for a sustainable development. Most of the Universities around the world, have design criteria and applications according to these rating systems.

2.4. Summary and Evaluation

This chapter firstly, presents a definition of the sustainability and sustainable campus with its role in the society. Then, gives the integration of sustainability approach to university campuses as well as its relation with campus operations and its developing process. Besides these, sustainable campus design principles are defined at some categories and their strategies are explained with the aim of reducing the environmental effects and sustainable campus examples with their strategies and their design guidelines at some categories are expressed. Lastly, Sustainable Campus Design measures in world and which universities applied these measures are explained and their sensitivities for environment are emphasized.

CHAPTER 3

EFFICIENT WATER MANAGEMENT FOR A SUSTAINABLE CAMPUS

In Chapter Three, firstly efficient water management approaches in history and present are presented and the differences between the countries' strategies are mentioned. Besides, Water harvesting techniques and their benefits are emphasized and how these techniques change according to the type of application site are explained.

3.1. Efficient Water Management Approaches

Earliest urban drainage structures were built about 5000 years ago in the time of the Mesopotamian. The major objectives of the urban drainage are to provide public hygiene, flood protection and environmental protection. With the historical problems, new problems arise depending on urban geography with population growth. These problems are; increasing quantities of water draining from impervious surfaces, deteriorating water quality, decrease of groundwater and increasing flooding (Chocat et al., 2007). Later, over the past decade urban drainage systems have moved through Sustainable Urban Drainage Systems or Best Management Practices to hold the rainwater or stormwater and be compatible with the environment. **Green Infrastructure** concept arised and took place of traditional systems. Green infrastructure design is engineering design that takes a "design with nature" approach or engineered green infrastructure is human-designed devices that mimic nature in function, or strive to reduce their impact on ecological systems and function. Green Infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff. It is a general concept that includes both greenways, native landscaping, porous pavement, swales, green roofs, wetland restoration and rain gardens.

Storm or surface runoff is a stormwater that moves on the ground by gravity and flows into streams, rivers, ponds, lakes and oceans. Urbanization effects the drainage

systems. Because of urbanization, the amount of the impervious surfaces such as; roofs, streets, parking lots and sidewalks increase. The amount of vegetated areas decrease. So; the stormwater runoff increase. When rainfall hits impervious surfaces such as roofs and sidewalk, stormwater runoff occurs. As stormwater flows through the streets and roads, it picks up the pollution like toxic particles from tires and brakes, motor oil, sediments, animal droppings, litter and other garbage. Also, stormwater runoff cause a flooding risk. Engineered solutions aren't proper for the sustainable environment and not cost effective, so natural drainage systems should be developed. Urban landscape should be redesigned according to the stormwater runoff. Integrated stormwater infrastructure needs more public green spaces. Trees have an important role because a single tree can absorbs 845 gallons to 2400 gallons stormwater per year. These numbers can change according to the tree type, canopy width, wind and the rainfall intensity. Rooftops have large percentage of the total area of the city so they have high potential for landscape areas with green roofs. Greenroofs both capture the rainwater and reduce the roof temperature. They help to reduce the urban heat-island effect (San Francisco Planning and Urban Research Association, 2006). In order to maintain our water resources and quality of life, we should take some precautions to protect and manage the stormwater. We also need to educate the people to realize how their actions effect the quantity and quality of the water (Annis Water Resources Institute, 2002).

Stormwater management strategies are for the prevention of stormwater runoff and hold and reuse it. In the world, most of the countries develop strategies and apply techniques to prevent the stormwater runoff. **In United States,** "Low Impact Development" concept is developed. Some techniques are used for proper stormwater management. Permeable pavement, rooftop rainwater collection system, bioretention areas, green roofs, open road sections with vegetated swales are the techniques that are used to protect streams, wildlife habitat, wetlands and other natural resources, groundwater and drinking water supplies (Tilley, 2003). Also, **In California**, buildings are designed as a part of stormwater systems. They want to demonstrate how can a single parcel work as a watershed and think of the whole parcel connected network to meet the region's water management and flood prevention needs. Cistern system, vegetated and mulched swale are the part of the system. Site selection is important for the system. Also, trees and landscape, soil type, monİtoring the soil and stormwater treatment systems play an important role in the system (Horin, 2007). On the other hand, **In Portland**, "green street" concept is developed. The state has planned the

streets green as a function of capture stormwater and reuse it and recharge groundwater. The green street applications are done with stormwater curb extensions, stormwater street planters, rain gardens and simple green streets (Portland Bureau of Environmental Services, 2010). **In Europe and U.K.** ; "Sustainable Urban Drainage System (SUDS)" concept is developed and this concept is used in applications. The aim of the SUDS is to protect the water quality and prevent pollution, reduce quantity and velocity of surface water runoff at source and design of physical structures to receive the runoff. Greenroofs, Permeable Pavements, Rainwater Harvesting, Infiltration Basins and Infiltration Trenches are the techniques used by SUDS (Environment-agency, 2010). **In Australia,** "Water Sensitive Urban Design" concept is used to emphasize the stormwater management. Water sensitive urban design (WSDU) include stormwater, drinking water and waste water management to protect water related environmental, recreational and cultural values. WSDU aims to restore the natural water balance, reduce flood risk in urban areas, improve and protect water quality, reduce the cost of the water infrastructure, integrate water into landscape design, reduce greenhouse gas emission and increase rainwater harvesting and natural treatment alternatives. WSUD can be applied at different scales from single residential development to public open space. WSUD develop water demand reduction techniques. These are; water efficient fixtures, water efficient landscaping with efficient irrigation, rainwater storage, stormwater storage, reuse greywater and reuse treated wastewater (Department of Planning and Local Government, 2009).

Water harvesting is essential for an effective water management because the main aim is protecting the water quantity and quality of water resources. There are various resources to capture water (Table 3.1). Rainwater, stormwater, greywater, air-conditioner condensate, treated wastewater and desalinated water are important resources. Rainwater is collected from rooftop surfaces, it is not proper for potable uses but can be used for toilet flushing, irrigation and cooling equipment but it can be potable if treated. Stormwater is getting from impervious surfaces like roads, pathways, plazas, car parks like that. It has the same using areas with rainwater. Greywater collected in buildings from the showers, bathtubs, clothes washers and lavatory faucets, is proper for non-potable uses and can be used for irrigation. Another one is air-conditioner condensate. It is an important source for hot and humid regions. Condensate is moisture removed from indoor air. Condensate captured from the evaporator coils of air-conditioning equipment and proper for non-potable uses and can be used for toilet

flushing, irrigation and cooling equipment. Treated waste water is also used as a resource that can be used for irrigation, toilet flushing and cooling equipment and lastly desalinated water is a freshwater produced by removing salts from sea water and it is proper for potable uses (Environmental Building News, 2010).

Table 3.1 Alternative Water Sources
(Source: Environmental Building News, 2010)

Source	Definition	Typical Uses	Requirements	Pros & Cons
Graywater	Wastewater collected in buildings from showers, bathtubs, clothes washers, and lavatory faucets (but never from toilets and usually not from kitchen sinks or dishwashers)	Nonpotable: usually used for subsurface irrigation	Separate wastewater drainage lines for graywater and blackwater, a filtration system, and usually storage; sometimes fed directly into subsurface irrigation piping	+ Reduces demand for freshwater + Water volumes can be large + Can provide irrigation during droughts – Difficulties with permits – Cost of dual piping – Risk of smell – Maintenance requirements
Rooftop rainwater harvesting	Rainfall collected from a roof surface	Nonpotable: used for toilet flushing, irrigation, makeup water for cooling equipment; potable if adequately treated	A gutter system to channel rainwater into a cistern or rainbarrel; often first-flush and filtration systems; treatment for potable uses Most practical in climates that receive at least 20" (50 cm) of rain per year	+ Reduces demand for freshwater + Rainwater is generally softer than well water + Avoided energy for pumping (if gravity-fed from a cistern) – When rainwater relied on as sole potable water system, adequate storage is expensive
Landscape-scale stormwater harvesting	Stormwater collected on parking areas or other low-permeability landscape surfaces and stored in retention ponds	Nonpotable: used for toilet flushing, makeup water for cooling equipment	Topography that channels stormwater into retention ponds, mechanism for withdrawal and use	+ Reduces demand for freshwater + Fairly low cost – Difficult to manage stored water due to evaporation, vegetation
Air-conditioner condensate	Condensate captured from the evaporator coils of air-conditioning equipment or dehumidifiers; the condensate is moisture removed from indoor air	Nonpotable: used for toilet flushing, irrigation, makeup water for cooling equipment	Drainage of condensate lines into storage for later reuse; only feasible in areas with adequate indoor humidity levels (not as feasible in much of the western U.S.)	+ Reduces demand for freshwater + As distilled water, condensate is initially very pure + Water volumes can be large – Potential for contamination of stored condensate and condensate lines
Mechanical equipment blowdown	Water bled from cooling towers and other mechanical equipment	Nonpotable: depending on dissolved minerals and contaminants, may be used for irrigation	Collection and storage components integrated with cooling towers or other sources of blowdown water	+ Reduces demand for freshwater + Water volumes can be large – Most blowdown water has high mineral content or other contaminants
Treated wastewater (building-scale)	Onsite treated wastewater (graywater and blackwater), producing nonpotable water	Nonpotable: used for toilet flushing, irrigation, makeup water for cooling equipment	A sophisticated onsite treatment system employing biological action, microfiltration, sometimes reverse osmosis, UV or chemical purification; ecological wastewater treatment may be employed	+ Reduces demand for freshwater – High installation cost – Sludge disposal remains – Can be energy intensive
Treated wastewater (municipal)	Outflow from a sewage treatment plant after tertiary treatment and purification; distributed from water utility through separate piping for nonpotable uses	Nonpotable: used for toilet flushing, irrigation, and makeup water for cooling equipment; may someday become acceptable as potable water	Separate supply plumbing for potable and nonpotable water; some water utilities provide such piping—most commonly tied to dedicated landscape irrigation systems	+ Reduces demand for freshwater + Energy savings compared with potable water use – Perception that treated wastewater is unsanitary or dirty
Desalinated water	Freshwater produced by removing salts from seawater or brackish water	Potable; generally too expensive for nonpotable uses	Most desalination plants use reverse osmosis—forcing salt water through a specialized membrane that excludes salts	+ Reduces demand for freshwater + Virtually unlimited supply – Energy intensive – Potential for increasing salinity in bays or evaporation ponds where desalination backwash is deposited

3.2. Stormwater and Rainwater Harvesting Techniques

Stormwater and Rainwater harvesting systems are more cost- effective water suppliers. This is important for all arid and semi-arid regions. These water supply techniques have regional importance for the conservation of limited ground and surface water supplies (Kinkade, 2007). **Rainwater** is a water supply that is harvested from the rooftops. Rainwater is a free source of nearly pure water. It can be used to supply potable and non-potable uses. For potable uses rainwater must be treated to remove the organisms in it and must go through several steps; screening, settling, filtering and disinfecting. Many cultures around the world have used harvested rainwater. The Middle East, Asia, Ancient Rome and Mexico applied rainwater harvesting techniques. In history, most of the house had rainwater collecting cisterns, the design of the house had been done with harvesting system. The size of the cisterns changed from 35 to 200 cubic meters. In Roma, rainwater is collected from the covered walkways and directed to the small pools located in the gardens both for aesthetic function and future irrigation water supply. In the U.S and Canada the rainwater harvesting systems have been used by the inhabitants and the settlers who have been living in isolated areas that have no municipal water supplies.

Stormwater is a water supply that is harvested from the impervious ground surfaces like sidewalks, parking lots and plazas. Stormwater collected from ground-level catchment areas shouldn't be used for potable purposes. Rainwater and Stormwater harvesting consist six primary components: Catchment, conveyance, filtration, storage, distribution and purification. The amount of the water collected depends on catchment size, surface texture, surface permeability and slope (Gupta and Ashok, 2007) . For a Water sensitive urban design, there should be some considerations. Firstly, site analysis is important. Topography of the site, existing natural features, orientation of the site, kinds of plants, existing buildings, soil type should be considered (Department of Planning and Local Government, 2009).

As a result, all these applications are for reducing water consumption, protecting the potable water resources and increasing the water quality. Also, this will help energy saving, because the process of water that extracts from surface and groundwater supplies and bring it to treatment facilities then treating it to drinking water standards and delivering it to residential and commercial customers cause energy consumption.

Green Roofs, Rainwater and Stormwater Storage Techniques, Sustainable Stormwater Drainage Systems, Stormwater Basins, Pervious Paving, Green Streets, Green Parking, Efficient Landscape and Irrigation and Grey water Systems are the rainwater or stormwater harvesting techniques.

3.2.1. Green Roofs

Green roof is a one of the techniques for rainwater harvesting systems. Rooftops account large percentage of the total area of the city so they have high potential for landscaped areas. Green roofs prevent rainwater from entering the stormwater system. They are the self-sufficient systems that provide the water need by rainfall. Green roofs also have ability to reduce the temperature on the roof surface in summer (San Francisco Planning and Urban Research Association, 2006). Green Roofs are a series of layers consisting of living vegetation growing in substrate over a drainage layer (Department of Planning and Local Government, 2009). **A green roof** or eco-roof is a planted roof top that provides benefits of water harvesting, stormwater quality improvement, energy conservation, pollution reduction, heat-island effect reduction, aesthetic value improvement and air pollution filtering (University of Florida, 2008). There are two types of green roofs. These are the extensive and intensive green roofs. Their characteristic features are changing according to their purpose, substrate type and depth, plant type, irrigation demand, maintenance, cost, accessibility and runoff percentage (Table 3.2).

Table 3.2. Comparison of Extensive and Intensive Green Roofs
(Source: Novotny, Ahern and Brown, 2010, p.192)

Characteristics	**Extensive Roof**	**Intensive Roof**
Purpose	Functional,stormwater management,thermal insulation, fireproofing	Functional and aesthetic,increased living space
Substrate Type	Lightweight, high porosity, low organic matter	Lightweight to heavy, high porosity, low organic matter
Average Substrate Depth	2 to 15 cm	15 cm or more
Plant Communities	Low-growing(Stresed tolerant plants, mosses,sedums)	No restrictions
Irrigation	None required	Often required
Maintenance	Little or no maintenance required	Some maintenance required
Cost	100$ to 300$ per m2	200$ per m2 or more
Accessibility	Generally functional rather than accessible	Typically accessible, recreational function
Percent Runoff From Rainfall	20-75 (depending on slope of the roof and vegetation)	15-35 (depending on slope of the roof and vegetation)

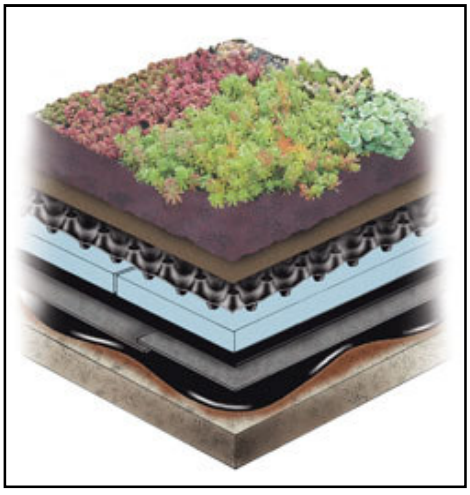


Figure 3.1. Extensive Roof
(Source: Hydrotechusa-1, 2010)

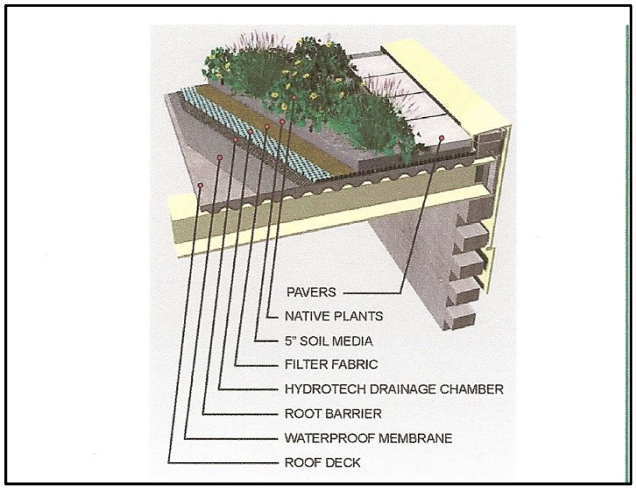


Figure 3.2. Extensive Roof Section
(Source: Buildgreen, 2010)

Extensive Green Roofs are not intended for recreational use, they are chosen for reducing stormwater runoff and heat island effect, their appearance and increasing the air quality. They can be applied both flat and sloping roofs. The detail layers of extensive roof are shown in (Figure 3.1 and 3.2).



Figure 3.3. Extensive Roof / Vancouver CityLibrary
(Source: Hydrotechusa-2, 2010)



Figure 3.4. Extensive Roof / University of Florida
(Source: Buildgreen, 2010)

Intensive Green Roofs are intended for recreational purposes. They have the same design concept with the extensive roof. Both the hard and soft landscape is using for the intensive one. Also, intensive roofs have drainage/retention layer but the water is used for the roof's irrigation.



Figure 3.5. Intensive Green Roof Detail
(Source: Hydrotechusa-1, 2010)



Figure 3.6. Intensive Green Roof
LDS Conference Center,
Salt Lake City, UT
(Source: Hydrotechusa-2, 2010)

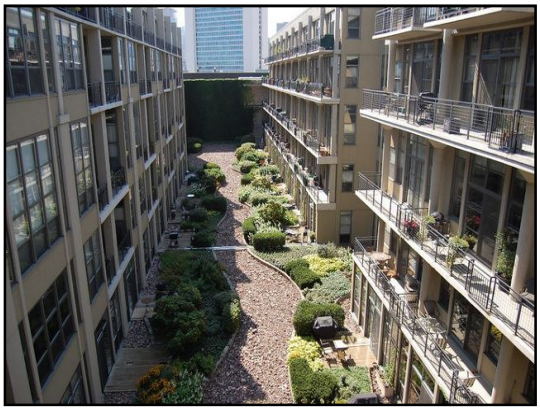


Figure 3.7. Intensive Green Roof
Kingsbury, Chicago, IL
(Source: Hydrotechusa-2, 2010)

3.2.2. Rainwater and Stormwater Storage Techniques

Rainwater and Stormwater storage systems are part of stormwater management techniques. The aim of the system is to storage the rain or stormwater to reuse for water related works or activities. Roof Water Retention Tanks, Cisterns and Barrels are the underground or above water collection systems that are hold rainwater from the roof and reuse for irrigation. These systems are generally connected with gutters or downspouts of a building.

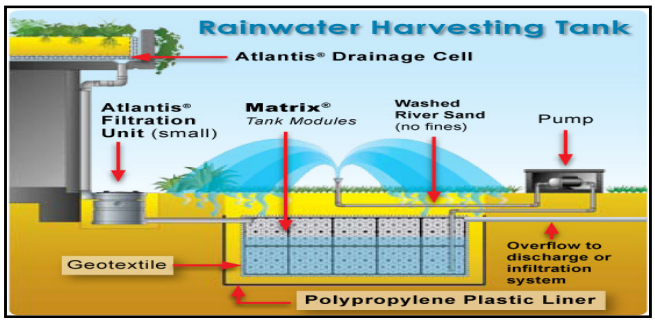


Figure 3.8. Water Retention Tank
(Source: Infolink, 2010)

These systems are used both for flat roofs and green roofs (Figure 3.8). In both of them, rainwater is collected from roofs directed to the retention tank system with downspouts of the building.

On the other hand, conveyances are the important elements of the drainage system for rainwater collection from roof (Figure 3.9 and 3.10). They direct rainwater drained from downspouts through planted areas to infiltrate.



Figure 3.9. Rainwater Conveyance
(Source: Brgov, 2010)



Figure 3.10. Rainwater Conveyance
(Source: Brgov, 2010)

Rainbarrels and Cisterns are used in small scale to collect rainwater and surface detention ponds are created in large scale, to capture and recycle stormwater for non – potable needs. **Cisterns** can be located above or below ground, depending on site conditions (Figure 3.12). Cisterns should not be placed near trees whose roots may damage the cistern walls. **Rain barrels**, often made from 208 liter plastic drums. Residential rain barrels are an inexpensive and easy retrofit that reduces stormwater runoff and provides water for irrigation (Figure 3.11 and 3.13). Reuse systems provide benefits of conservation of potable water and improvement of water treatment (Buildgreen, 2010).

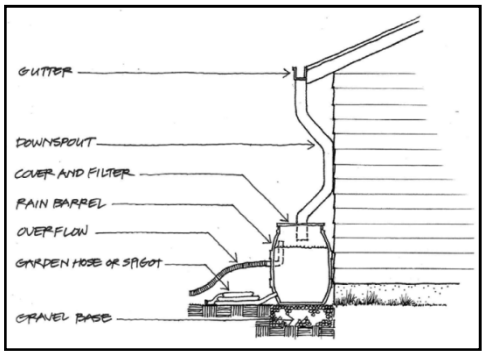


Figure 3.11. Barrel
(Source: Buildgreen, 2010)



Figure 3.12. Cistern/University of Florida
(Source: Buildgreen, 2010)



Figure 3.13. Barrel
(Source: Epa, 2009)

3.2.3. Sustainable Stormwater Drainage Systems

Sustainable Stormwater Drainage Systems are different from the traditional drainage systems. These systems do not damage the environment on the contrary; they protect the environment and habitats. Natural Drainage ways are used to capture the stormwater and reuse it for other uses. Swales, Stormwater Basins, Rain Gardens, Ponds and Wetlands generate drainage system.

Swales

There are two kinds of swales: Bio-Swales and Vegetative Swales

Bio-Swales (Dry Swale): Bio-Swales or Dry Swales are type of open vegetated channels with an underdrain, which may not need naturally well drain soils, used to treat and reduce the quantity of stormwater runoff. Surface runoff from the adjacent impervious area enters the swale diffuselly through an gravel strip and then flows through a vegetated buffer along the edge of the bioswale. Bioswales are often integrated into parking lots, road medians and parallel to road ways. This type of swale is proper for residential areas because there isn't long standing water. If the existing soil type of the Bio-Swale isn't permeable, it will be changed with permeable sand/soil mix. This type swale provides to remove sediments and pollutants, to control the peak discharge with reducing runoff and groundwater recharge. Native plants are best for enhancing the biodiversity, infiltration and drought tolerance (Metrocouncil, 2010).

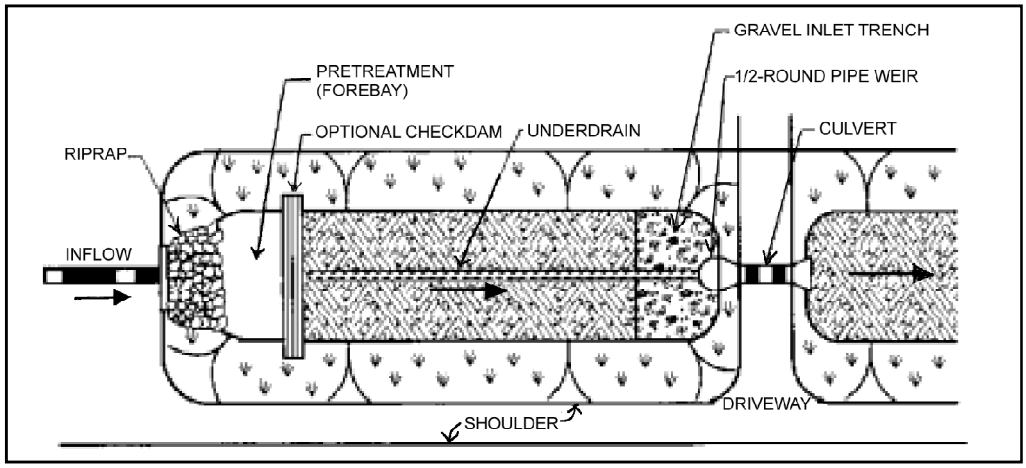


Figure 3.14. Bio (Dry) Swale Plan View
(Source: Stormwatercenter, 2010)

Bio or Dry Swales should be designed to treat small and flat drainage areas. The areas larger than 2.2 ha and have steep slope are not proper for effective treatment and erosion because of the flow velocity of water. If dry or bio swales sited on step slope area, they must run parallel to contours to be effective. Generally, the bottom of the swale should be at least 1 meter above groundwater in order to prevent groundwater from being contaminated (Metrocouncil, 2010).

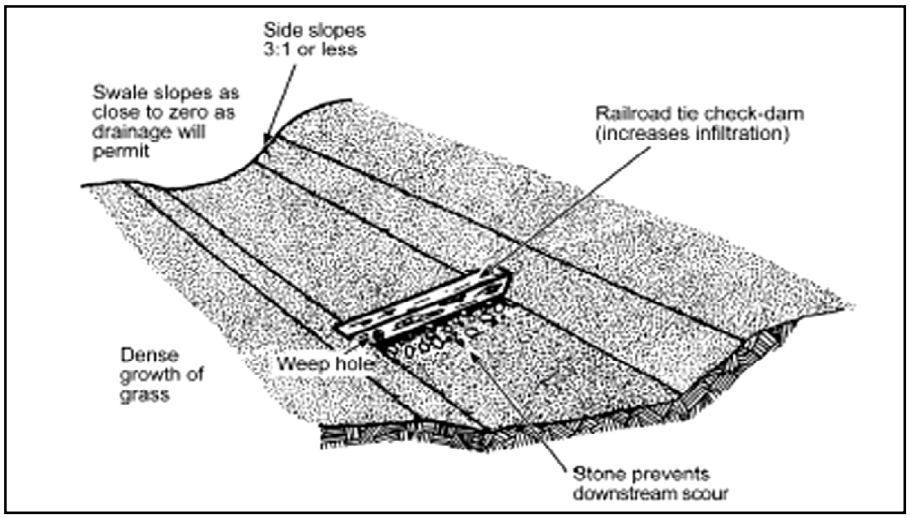


Figure 3.15. Bio (Dry) Swale Detail
(Source: Metrocouncil, 2010)

As we see in detail (Figure 3.15), check-dams are installed between the inlet and the main body of the swale to prevent downstream scour. Check-dams are used to reduce the effective slope and provide to enhance the filtration with decrease the velocity of the flow.

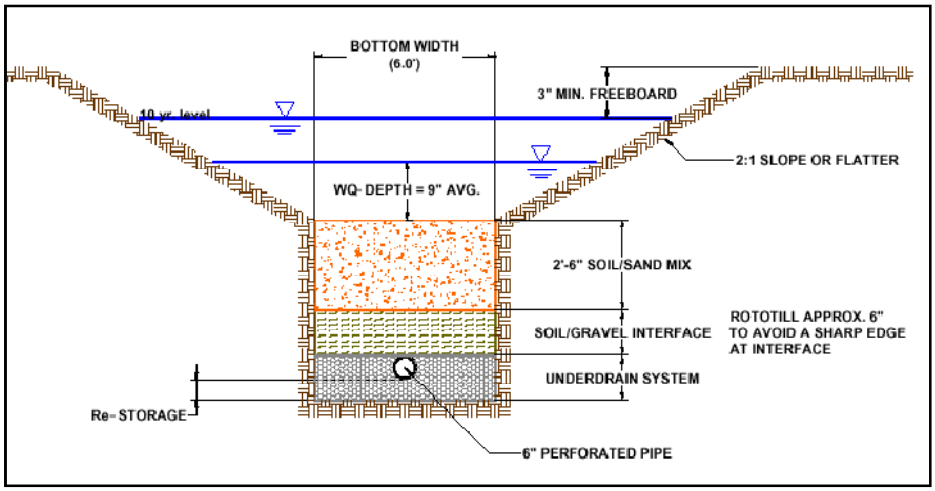


Figure 3.16. Bio (Dry) Swale Section
(Source: Metrocouncil, 2010)



Figure 3.17. Bio (Dry) Swale
(Source: Ecolandscapegroup, 2011)

Vegetated Swales (Wet Swale): Vegetated Swales (Wet Swales) are the open-channel drainage ways and alternative to traditional stormwater piping. They are impractical for areas with very flat grades or steep slopes and used to serve areas of less than 4.5 ha and with slope no greater than 5 %. Unlike bio-swales, vegetative swales do not have underlying filtering bed. The vegetated swale directly constructed with existing soil and behaves like wetlands to use of vegetation to treat stormwater runoff so the pollution removal is improved. It is aimed to reduce runoff capacity and improve the infiltration to recharge groundwater but when the soil is saturated with water, water stands on swale for a long time.

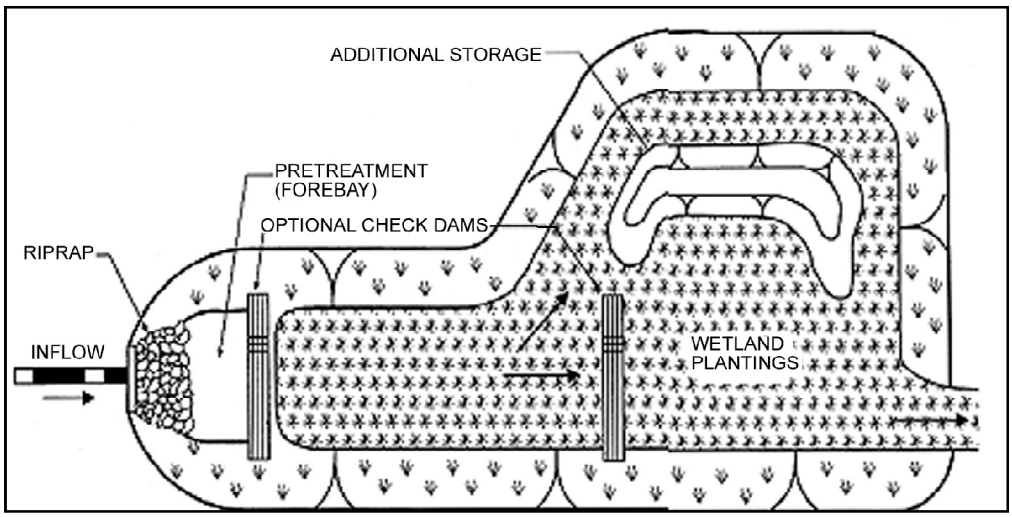


Figure 3.18. Vegetated (Wet) Swale Plan
(Source: Stormwatercenter, 2010)



Figure 3.19. Vegetated (Wet) Swale at Costsco Parking Lot
(Source: Werf, 2010)



Figure 3.20. Vegetated (Wet) Swale
(Source: Riversides, 2010)

3.2.4. Stormwater Basins

Stormwater basins are designed to store stormwater runoff temporarily (detention) or permanently (retention) to reduce flooding potential and to improve water quality. Storm water basins help to reduce flooding because the excessive water is hold in basin areas. Besides the storing and treatment function, basins provide recreational opportunities and have an aesthetic function with the unique plants and wildlife habitat. Stormwater basins are achieved with Bioretention Areas, Rain Gardens, Ponds, Wetlands, Filter Strips, Infiltration Basins, Filtration Trenchs and Planter Boxes.

Bioretention Areas: Bioretention is not a specific stormwater method; it is a general concept that can be applied in a wide variety of situations. Bioretention areas are filled with sand and soils to help infiltration and plant growth. Generally native plants are used to absorb runoff pollutants. They are suitable for parking lot islands, medians and other impervious surface drainage areas. They provide to reduce the runoff volume and treatment costs, also improve the water quality (Figure 3.21).

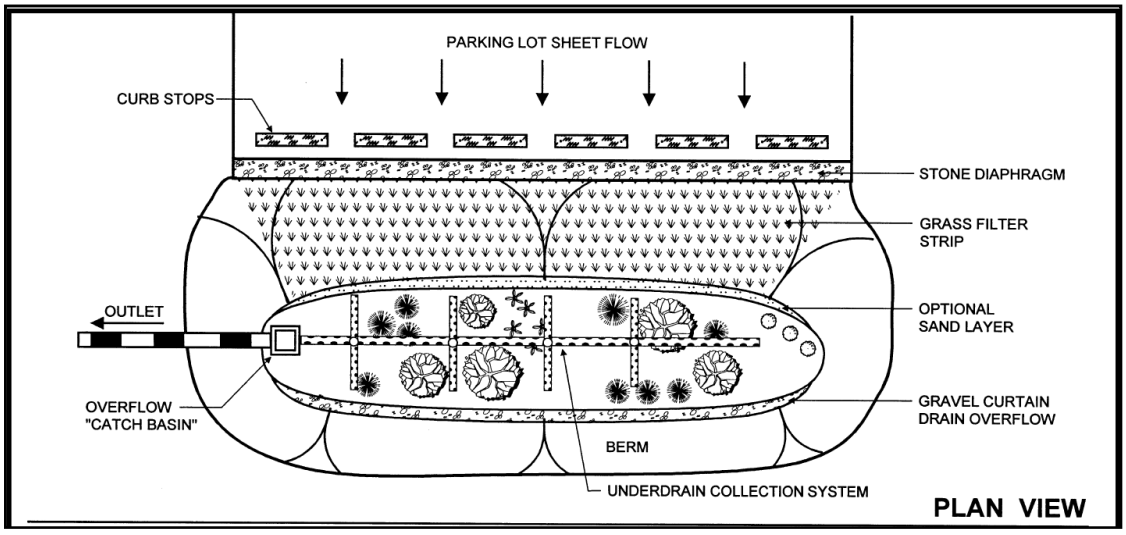


Figure 3.21. Bioretention Area Plan View
(Source: Georgiastormwater, 2010)

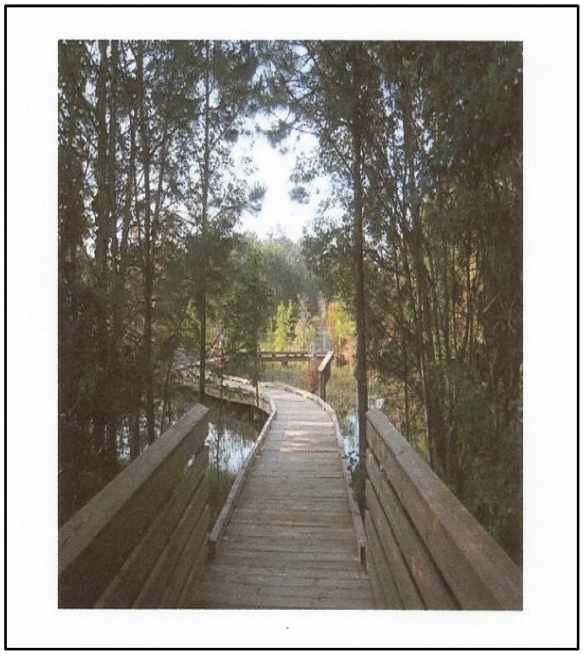


Figure 3.22. Bioretention/ University of Florida
(Source: Buildgreen, 2010)

Rain Gardens: Rain gardens are the small detention and infiltration gardens. Native plants are used to provide runoff volume control and to has aesthetic value. Rain gardens can be built on both sandy and clay soil. They are designed to capture the excess rainwater runoff from rooftops. The size of a rain garden depends on amount of runoff from the downspouts or impervious surfaces. Rain gardens and Bioretention areas are low areas where runoff water is diverted from the impervious surfaces such as roof tops, roads or parking areas. The purpose of the rain garden is to create more natural flow and keeping stormwater on site to infiltrate. Water should stand in a rain garden no longer than 48 hours after the rain stops. Rain gardens shouldn't increase mosquito populations because mosquitoes can't complete their breeding cycle in this length of time. Also, bioretention areas provide the same function with rain gardens but their locations are changing. Rain gardens usually locate in a residential or small landscape area but bioretention areas locate in larger commercial landscape settings (Seymour, 2005).

Ponds: Ponds are the parts of stormwater management system. They have function of storage and treatment. Ponds are divided into two; wet and dry detention ponds. Wet detention ponds have permanent pool of water from captured stormwater runoff. Dry ponds have temporarily pool of water for the excess of water in heavy rains. They are generally used for flood control. Dry ponds do not have function of pollution removal,

but infiltration system can be added to system (Novotn et al., 2010). A well designed stormwater pond should have a permanent pool of water, overlying zone in which runoff control volumes are stored and shallow littoral zone (aquatic bench) along the edge of the permanent pool to provide biological filtering. Also, all stormwater pond designs need to include a sediment forebay at the inflow to the basin to allow heavier sediments to drop out of a suspension before the runoff enters the permanent pool. Besides them, emergency spillway, maintenance access, safety bench, pond buffer and appropriate native landscaping are the design features of a pond (Figure 3.25) (Georgiastormwater, 2010).



Figure 3.23. Aerial View of Dell Pond /University of Virginia
(Source: Virginia, 2010)

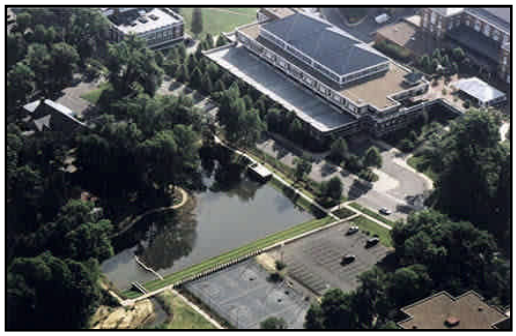


Figure 3.24. Dell Pond / University of Virginia
(Source: Virginia, 2010)

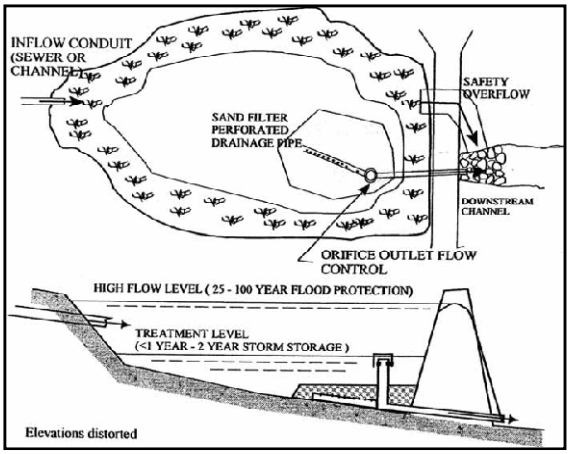


Figure 3.25. Dry Pond Plan and Elevation
(Source: Novotny et al., 2010)

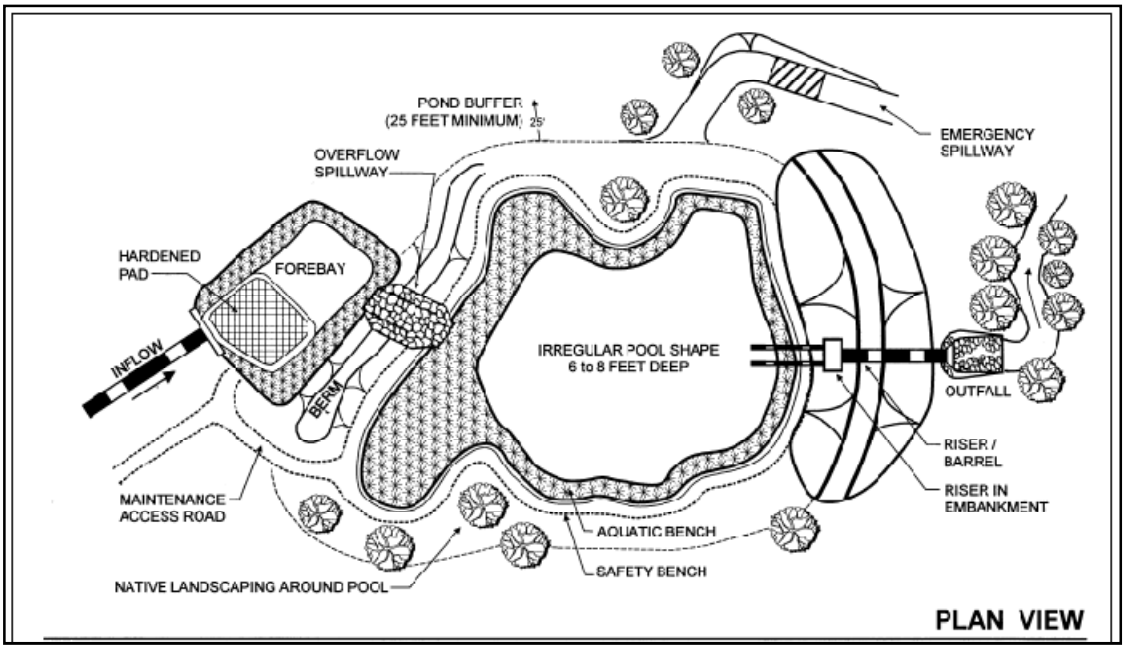


Figure 3.26. Wet Pond Plan
(Source: Stormwatercenter, 2010)

Wetlands: Stormwater Wetlands also referred constructed wetlands are constructed shallow marsh systems which are both designed for treating urban stormwater and controlling the runoff volumes. This system also provide to remove pollutants with marsh vegetation. Besides, stormwater controlling function, wetlands consist wildlife habitat and aesthetic value. Constructed wetlands differ from natural wetlands, so they are designed especially purpose of treating stormwater runoff. Drainage area of the

wetland should be at least 100.000 m^2 and 20.000 m^2 for pocket wetlands, also there should be no more than % 8 slope across the wetland site. Last, permeable soil is not proper for constructed wetlands. Like ponds wetland designs should include shallow marsh areas of varying depths with wetland vegetation, permanent micropool and overlying zone that stored the runoff control volumes. Also, all wetlands should have sediment forebay and other pond design features (Georgiastormwater, 2010).

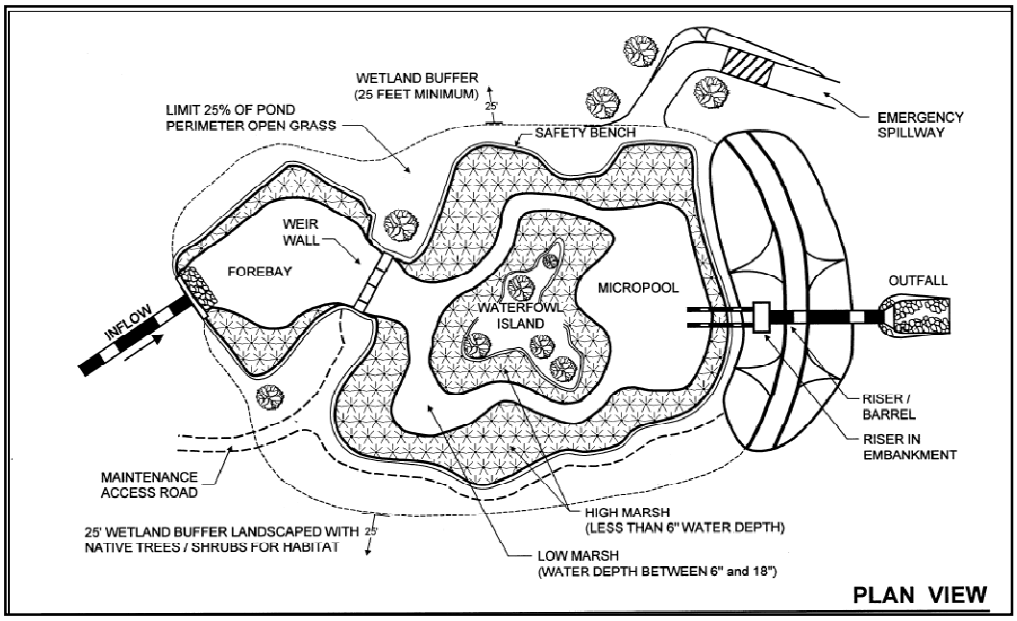


Figure 3.27. Constructed Wetland Plan
(Source: Georgiastormwater, 2010)

Filter Strips: Filter Strips are graded and densely vegetated sections of land. They are designed to slow the velocity of flow and treat stormwater runoff and remove pollutants through vegetative filtering. Filter Strips are suitable for treating runoff from roads, highways, roof downspouts, very small parking lots and pervious surfaces. They can serve as a buffer between incompatible land uses and help to recharge groundwater with pervious soil. Filter Strips have some design criteria; they should be used to treat small drainage areas, should be designed for slopes between % 2 and % 6 and should be at least 15 feet long to provide infiltration (Georgiastormwater, 2010).

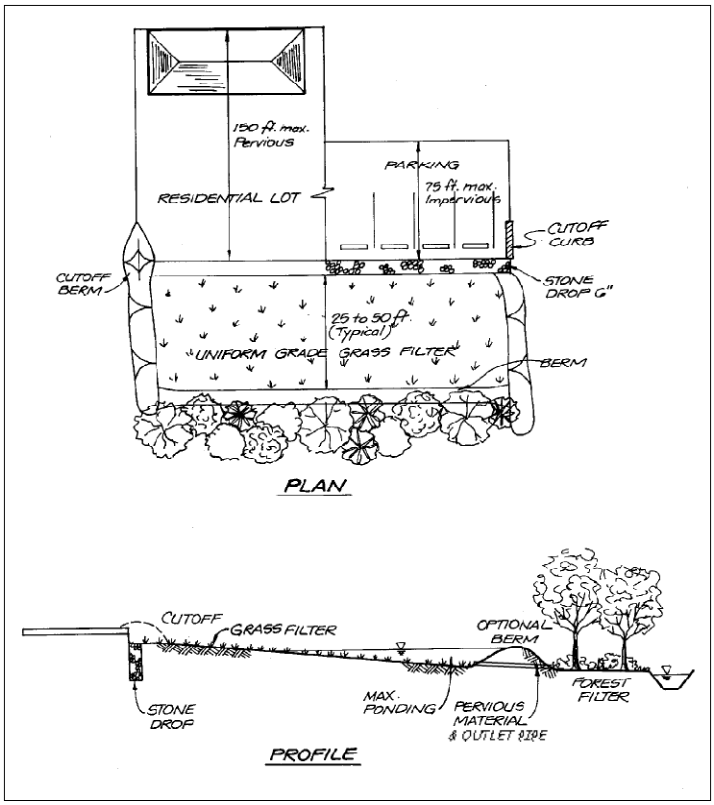


Figure 3.28. Filter Strip Plan and Profile
(Source: Georgiastormwater, 2010)

Infiltration Basins: Infiltration Basins are vegetated excavated areas that are designed to hold stormwater runoff and infiltrate into the ground so the soil type is important for infiltration basins, most permeable ones are the best. They have a function to be an end of a pipe for holding water from stormwater conveyance system like swale, channels or creeks like that. They are also effective to remove the pollutants from the stormwater. They are best for small size areas of two acres or less. Infiltration Basins are not designed for hold a permanent pool of water. They are not proper near industrial facilities where runoff is highly contaminated and should be located at least 45 m away from the drinking water well to limit contamination (Belan and Otto, 2004).



Figure 3.29. Filter Basin
(Source: Belan and Otto, 2004)

<u>Filter Trench</u>: Filter Trenches are excavated areas filled with stone to capture and help to infiltrate stormwater runoff and recharge groundwater. They also help to remove the pollutants. Well design infiltration trench should include excavated shallow trench filled with sand, stone, gravel, proper pretreatment measures and observation well to show how quickly the trench infiltrate.

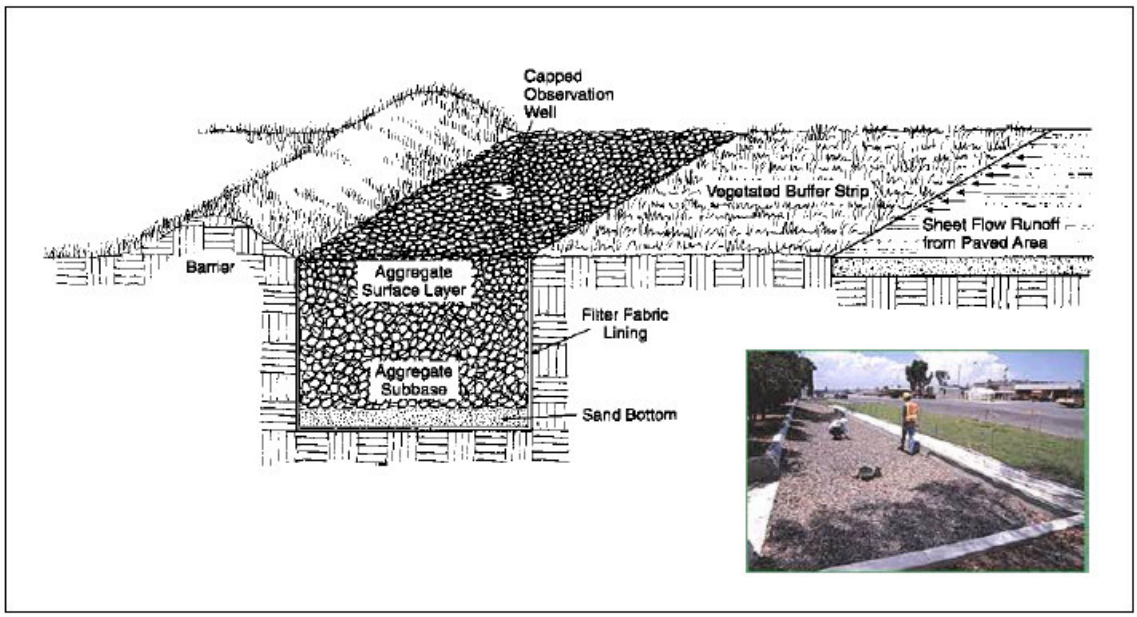


Figure 3.30. Infiltration Trench
(Source: Georgiastormwater, 2010)

Planter Box: Planter Boxes are the vegetated areas which receive runoff from rooftops so they should be located close to downspouts. Runoff is generally used for irrigation. They have the benefits of reducing runoff volumes.

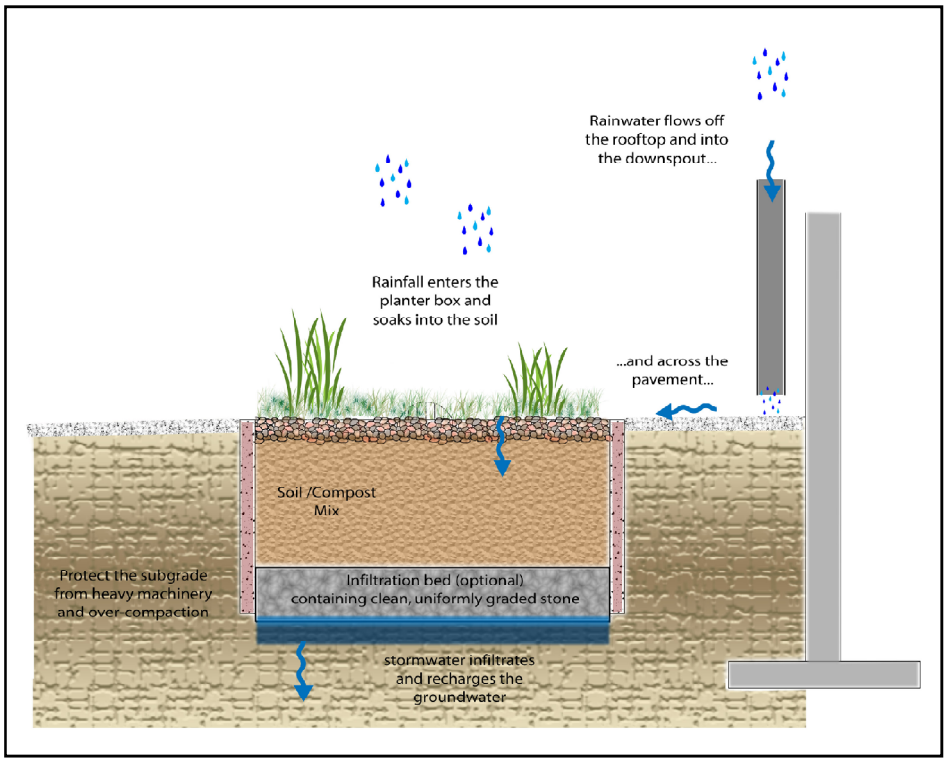


Figure 3.31. Planter Box Detail
(Source: Tredyffrin, 2011)

There are three type planter boxes. These are contained planter boxes, infiltration planter boxes and flow through planter boxes. Contained planter box shapes and sizes are changing according to runoff volume. Shrubs or trees are used as vegetation on them.

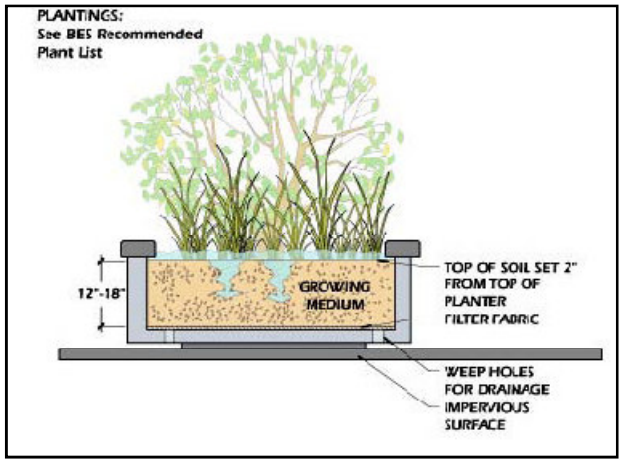


Figure 3.32. Contained Planter Box Section
(Source: Tredyffrin, 2011)



Figure 3.33. Contained Planter Box
(Source: Tredyffrin, 2011)

Infiltration Planter Boxes provide infiltration of the runoff from the roofs so they are generally located close to downspouts. Infiltration planter boxes are buried so stormwater can absorb into soil easily from bottom.



Figure 3.34. Infiltration Planter Box
(Source: Tredyffrin, 2011)

Last one is Flow Through Planter Boxes. Differently from the other planter boxes, this planter box type has overflow pipe for large storms.

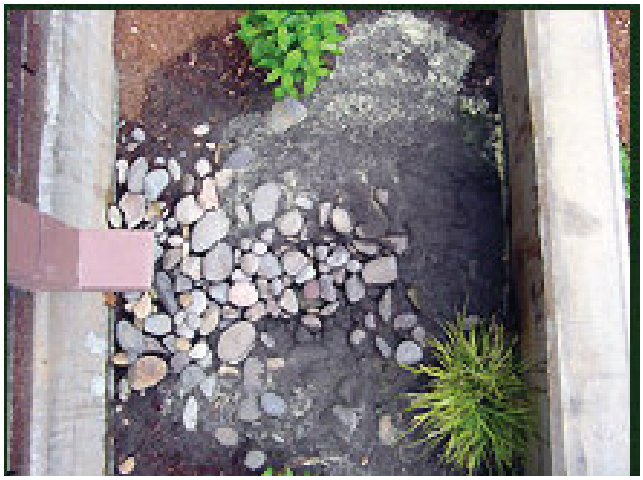


Figure 3.35. Flow Through Planter Box
(Source: Tredyffrin, 2011)

3.2.5. Pervious Paving

Pervious paving provides the structural integrity needed for cars, trucks and high traffic pedestrian areas, while allowing water to drain through the paving system and into soil below. The surface layer of the pervious pavement can be monolithic (porous asphalt or porous concrete) or modular (clay or concrete blocks) and the reservoir storage layer consist of crushed stone or gravel to store water before infiltrated to the underlying soil (Department of Planning and Local Government, 2010).

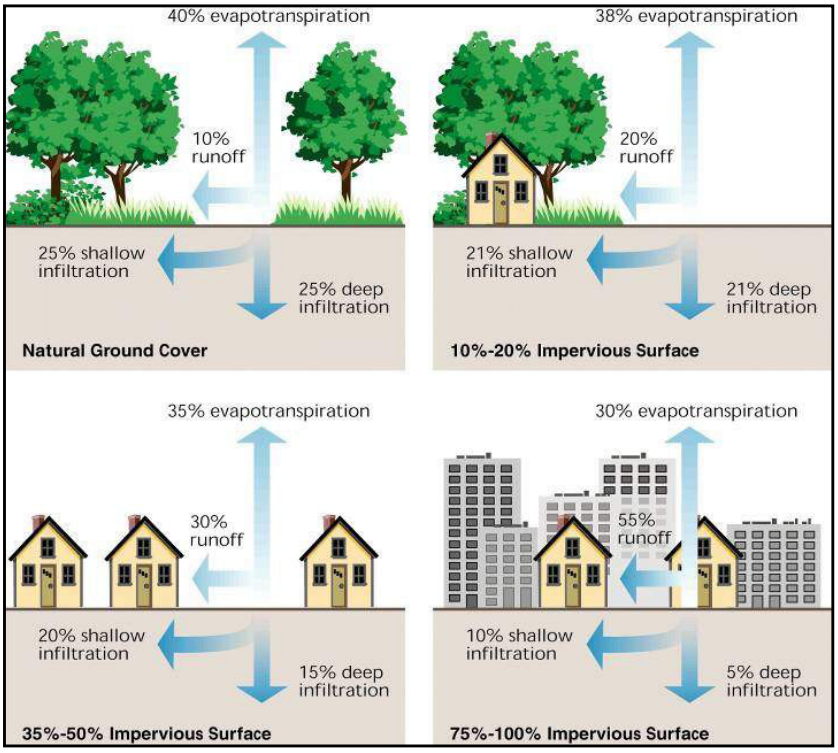


Figure 3.36. Surface Permeability
(Source: Brgov, 2010)

Permeability of the surface affects the stormwater runoff. The natural ground surface has high pervious and infiltration ratio but with the urbanization these ratios are changing (Figure 3.36). Pervious paving types are; pervious asphalt, concrete and structural grass- paving systems.

Gravelpave: Porous pavement allows to park, drive, walk, or ride easily and provide stormwater pollution filtration and treatment.



Figure 3.37. Materials of Gravelpave
(Source: Invisiblestructures, 2009)



Figure 3.38. Application of Gravelpave to surface
(Source: Invisiblestructures, 2009)

Grasspave: Porous pavement allows to park, drive, walk, ride, or lounge on a grass surface. It performs the functions of asphalt or concrete pavement and enhancing the environment. Also, Grasspave provides stormwater pollution filtration and treatment.



Figure 3.39. Materials of Grasspave (Source: Invisiblestructures, 2009)



Figure 3.40. Application of the Grasspave (Source: Invisiblestructures, 2009)

Slopetame: Slopetame is a permanent three-dimensional reinforcement and stabilization matrix for steep vegetated slopes and channel banks. The integral rings, bars, grid, and fabric act to contain upper root zone soils, allow vegetation roots to easily pass through, and minimize movement and loss by rain or flowing water.



Figure 3.41. Materials of Slopetame (Source: Invisiblestructures, 2009)



Figure 3.42. Application of Slopetame (Source: Invisiblestructures, 2009)

3.3. Green Street

Green Streets are the streets that use vegetated facilities to manage stormwater runoff at its source. Green Streets have function to reduce pollution from entering waterways, impervious surface, infrastructure cost, flooding and increase infiltration. Green Street Components are Inlet Design, Detention, Infiltration, Soils, Subgrade, Planting, Irrigation, Outlet and Overflow (Faha and King, 2009).

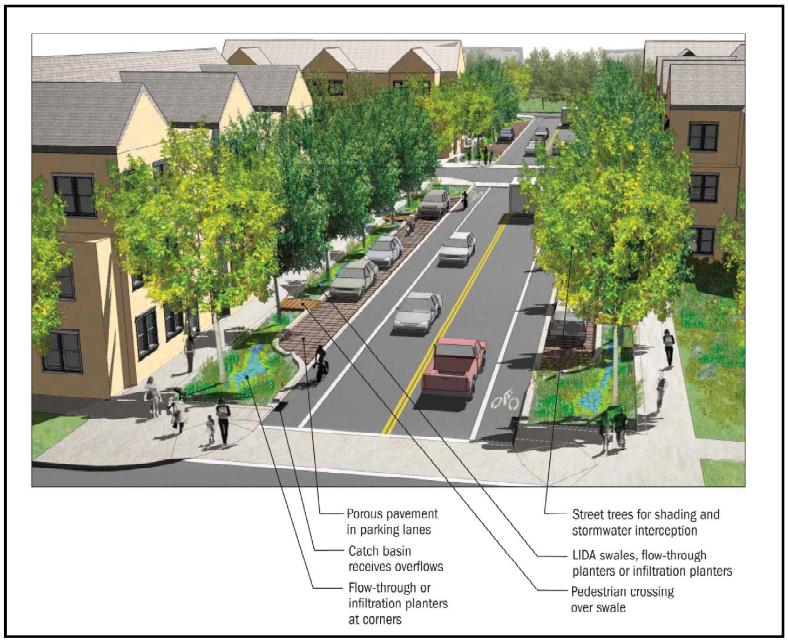


Figure 3.43. Part of a Local Stormwater System
(Source: Oeconline, 2009)

3.3.1. Application Types

The application types of the stormwater systems are curb extensions, curb-bulb outs, sidewalk planters and inlet designs. Both of them help to capture the stormwater and infiltrate it. These application types are also used in traffic calming techniques. Both of them are the traffic calming tools.

Curb Extension

On Roadway, vegetated curb extension areas are the filtration areas of stormwater runoff from the paved surfaces. They are located at corners or mid-block of paver. Mostly used in residential or commercial areas. The excessive runoff directed from the inlets through the curb extension area (Figure 3.44). There is a check dam in the middle of the area to slow the velocity of flow (Figure 3.45).



Figure 3.44. Ne Fremont Green Street, Portland
(Source: Oeconline, 2009)

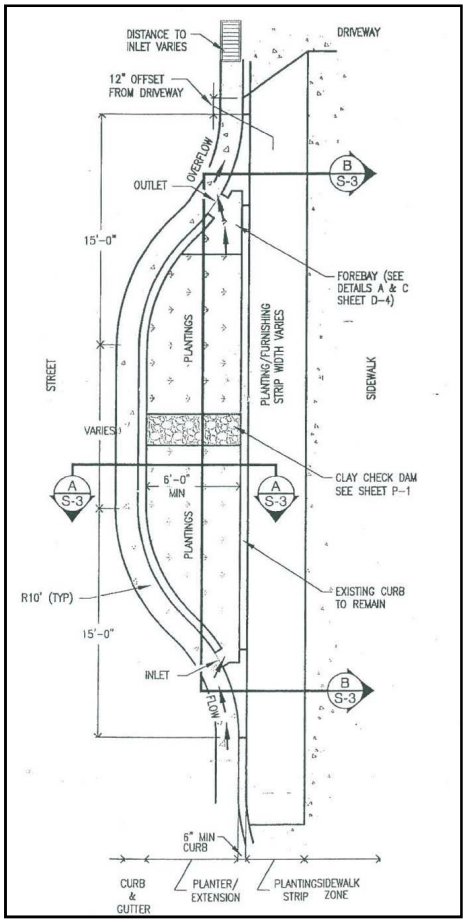


Figure 3.45. Plan of Curb Extension
(Source: Oeconline, 2009)



Figure 3.46. Siskiyu Street, Portland
(Source: Portlandonline, 2009)

CurbBulb-Outs

CurbBulb-Outs are the vegetated drainage elements on streets and located at the end of the block. The CurbBulb-Out area has two openings for drainage (Figure 3.47). These openings drain the stormwater runoff from the road through the vegetated area to provide the infiltration and treatment of the water.



Figure 3.47. Portland
(Source: Oeconline, 2009)

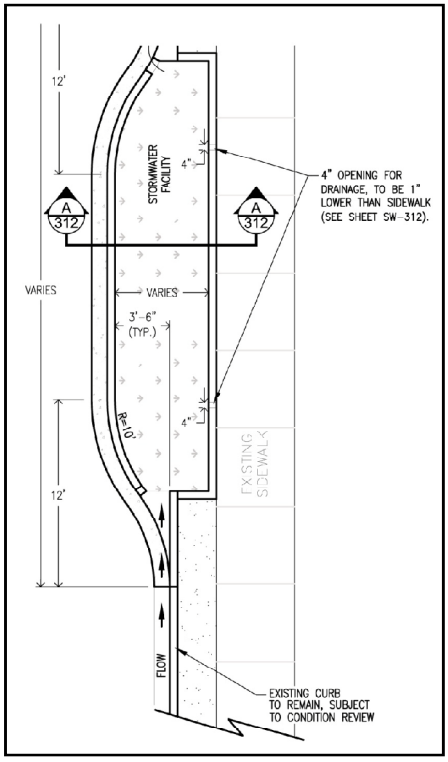


Figure 3.48. Plan of Curbbulb-Outs
(Source: Oeconline, 2009)

Sidewalk Planters

Sidewalk Planter is another drainage element to help drain the stormwater with non-slip gutters from the pavers (Figure 3.49). These planters provide the infiltration and treatment to recharge groundwater. They constitute the stormwater drainage way.

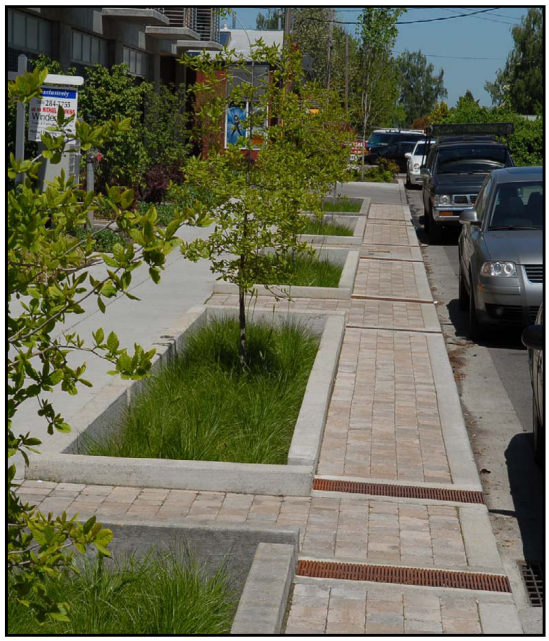


Figure 3.49. Portland
(Source: Oeconline, 2009)

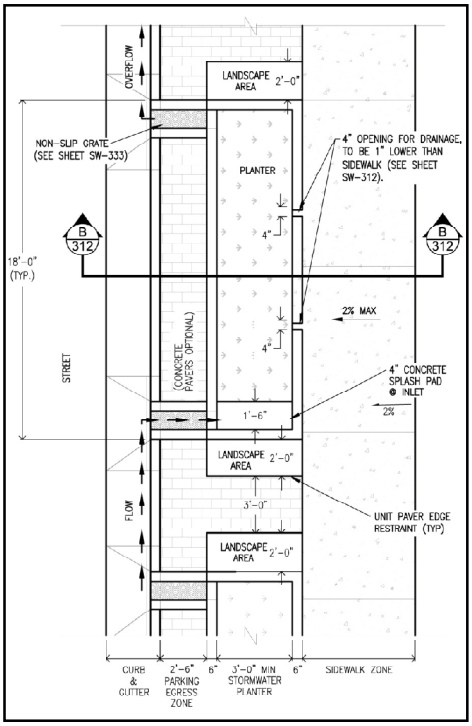


Figure 3.50. Plan of Sidewalk Planters
(Source: Oeconline, 2009)

Tree Wells or Tree Box Filter

Tree Well or Tree Box Filter is a stormwater harvesting technique that filter sediments and pollutants out of stormwater runoff. They are concrete structures installed in ground to control stormwater runoff quality and volume before entering a catch-basin. Structure is filled with soil filter media and planted with trees. Regardless the plant type, species with noninvasive root system should be selected to maintain soil infiltration rate. They are generally located on sidewalk alongside a street. The number of the units can change according to the site hydrology, climate, topography and tree box filter size (Ladstudios, 2011).

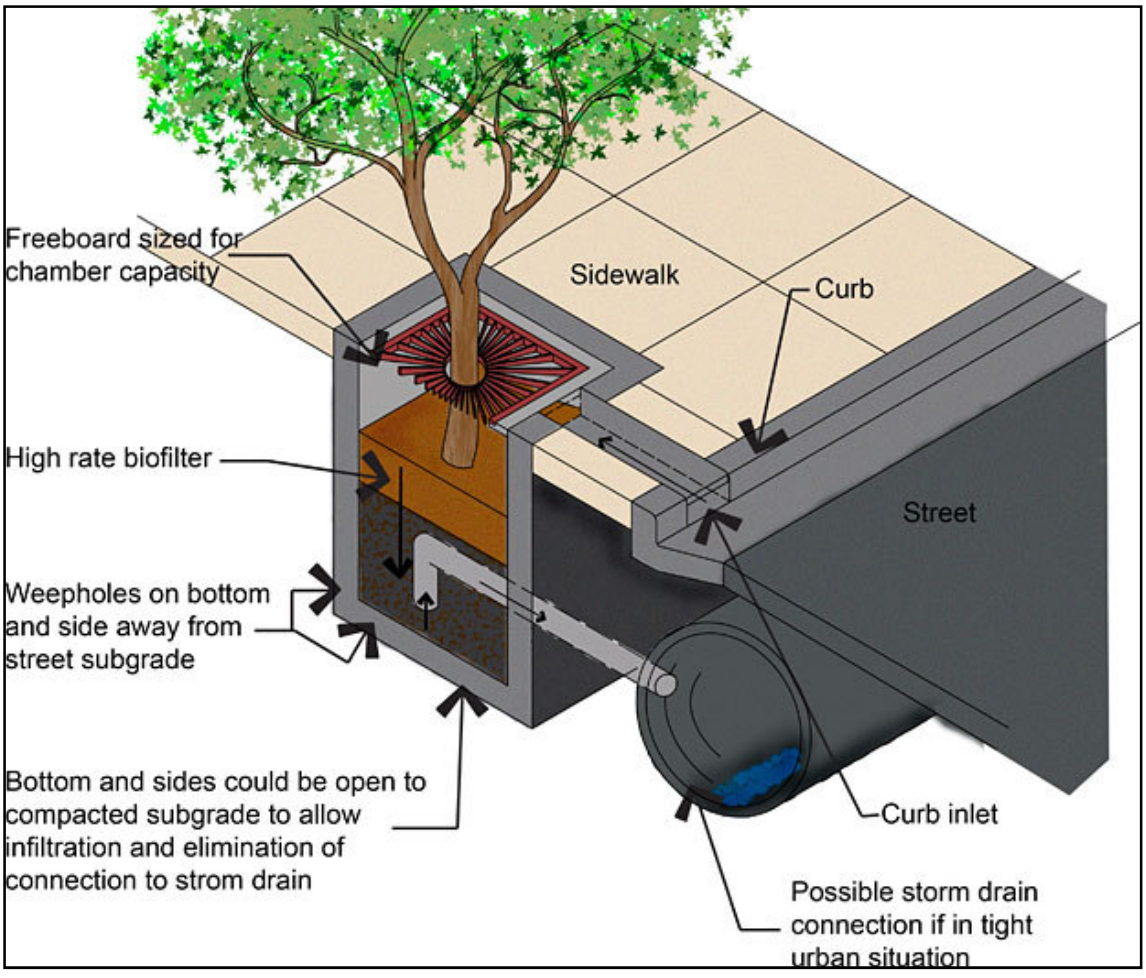


Figure 3.51. Tree Well or Tree Box Filter
(Source: Ladstudios, 2011)

Inlet Design

Lastly, Inlets are the supporter elements to help drain of the stormwater through the vegetative areas to infiltrate and added to drainage system (Figure 3.52, 3.53, 3.54). Generally, they are applied to pedestrian ways to hold the surface runoff from road and on parking lots to the swales with a function of draining the stormwater (Figure 3.55).



Figure 3.52. Inlet
(Source: Oeconline, 2009)



Figure 3.53. Inlet
(Source: Oeconline, 2009)



Figure 3.54. Inlet
(Source: Oeconline, 2009)

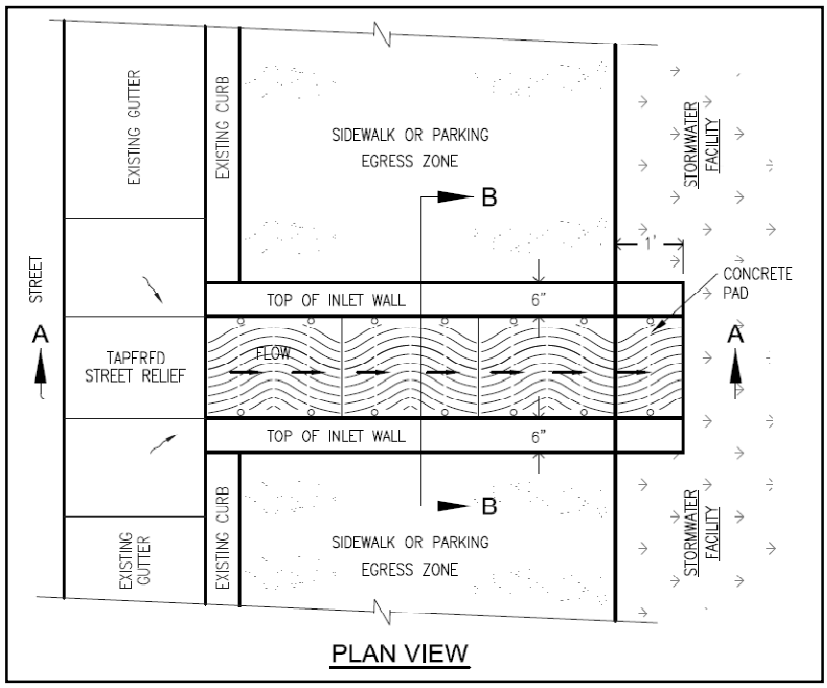


Figure 3.55. Inlet Design Plan View
(Source: Oeconline, 2009)

3.4. Green Parking

Parking Lots with green design have guidelines for stormwater management. The applied strategies are; minimizing the impermeable surfaces, manage the stormwater on-site with planting trees and other absorbent landscaping throughout the parking lot to provide shade and water capture, additionally bio-retention areas such as swales, vegetated islands and ponds are created. Green parking systems are more sensitive to the environment; some of the designs include the stormwater harvesting systems and help to hold the stormwater. Generally, swales and planter boxes are used to hold the stormwater and convey it to the drainage system and surface of the parking lot is mostly pervious.

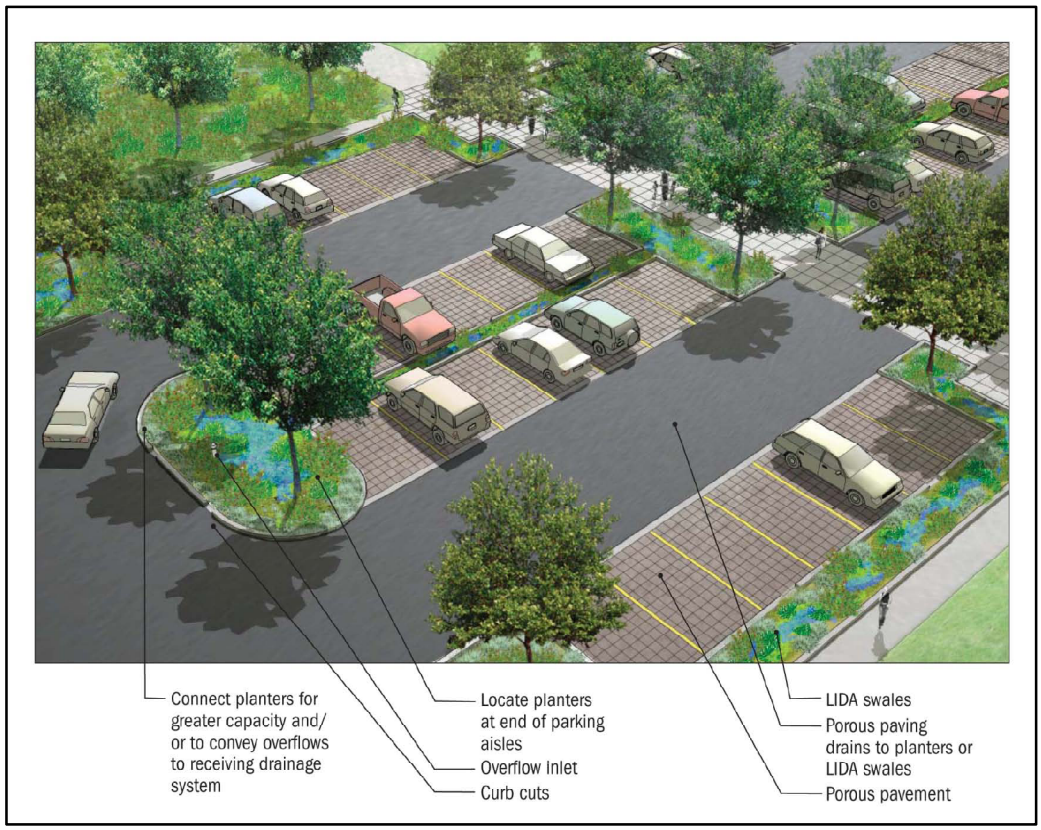


Figure 3.56. Green Parking
(Source: Oeconline, 2009)

In this green parking system (Figure 3.56), there are swales between the parking areas and at the end of the parking aisles, basin area is created to hold overflow of the stormwater drained from the swales. Also, with the curb cuts, the runoff from the asphalt surface is directed through the vegetated area.

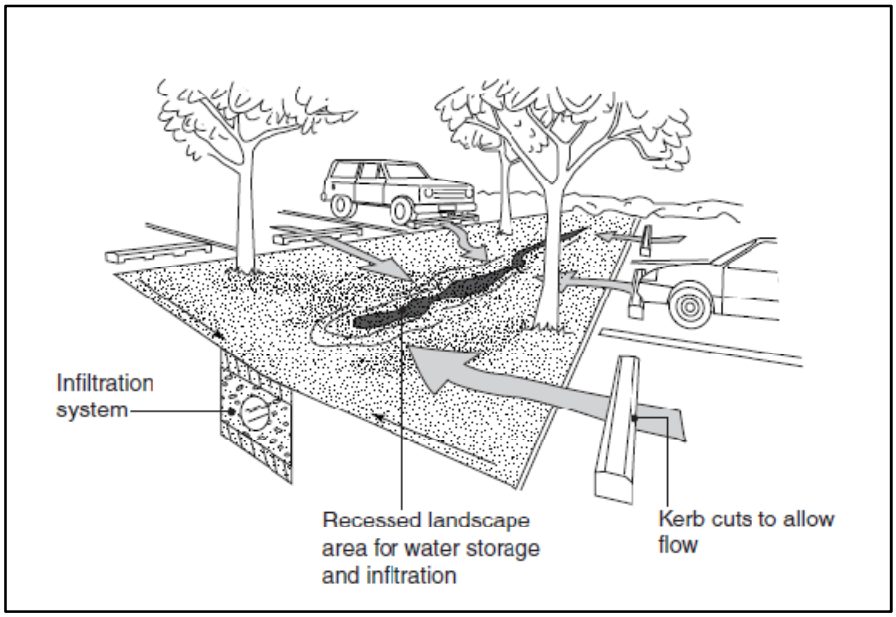


Figure 3.57. Gently Sloping Grassed Area on Parking Lot
(Source: Melbourne Water Corporation, 1999)

In design of Bio-retention Swale on parking lots, plant species should be selected according the conditions of flooding and drought. Also, the soil type is very important for the function of infiltration. There should be planted tree part above grade from the pond areas to clear stormwater entering from the curbs to the parking lot area (Figure 3.58) (Toronto City Planning, 2007).

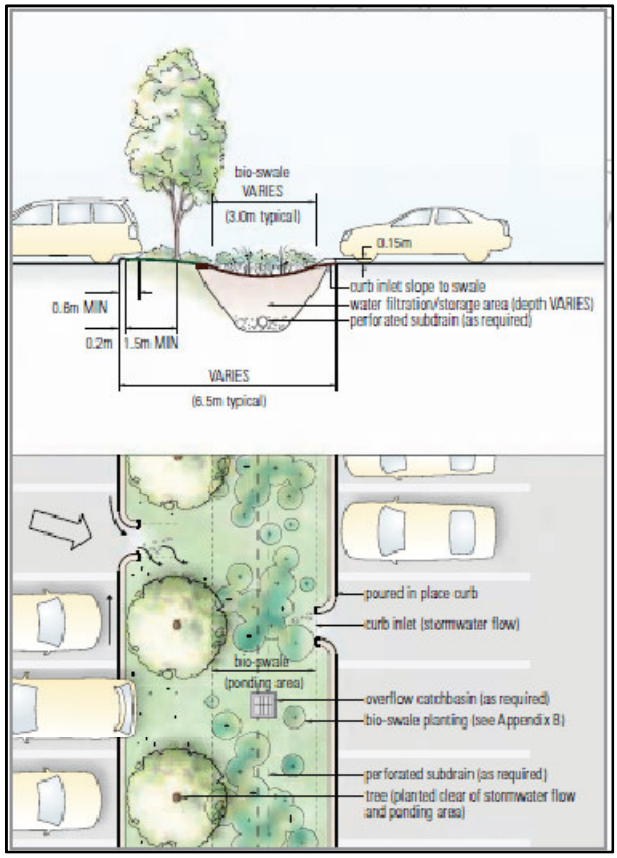


Figure 3.58. Design Concept for Bio-retention Swale
(Source: Toronto City Planning, 2007)

On the otherhand, Green Parking Lot design should aim to create direct, comfortable and safe pedestrian routes, provide shade (Figure 3.60) and high quality landscaping, mitigate the urban heat island effect, manage stormwater quality and quantity on site and use sustainable materials and technologies.



Figure 3.59. Landscape Street Edge
(Source: Oeconline, 2009)



Figure 3.60. Shade within the Lot
(Source: Toronto City Planning, 2007)



Figure 3.61. Bio-retention Area
(Source: Toronto City Planning, 2007)



Figure 3.62. Permeable Surface
(Source: Toronto City Planning, 2007)

Open Joint Pavers provide opportunity to infiltrate the stormwater to underground storage systems and pervious paving prevents the puddles on surfaces on rainy days (Figure 3.62).

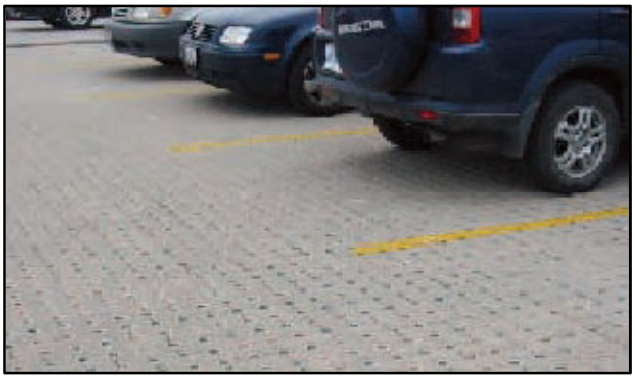


Figure 3.63. Pervious Paving
(Source: Toronto City Planning, 2007)

3.5. Efficient Landscape and Irrigation

Landscape Design does not have only an aesthetic function for urban design but also, it has function of supporting stormwater management. Integrating the landscape design with stormwater management reduces the quantity of runoff and provides maximum treatment on-site contaminants. Most of the case studies shows that if landscape designs are created according to stormwater drainage techniques, stormwater runoff can be prevented with native plants and special soils and the cost of piping can

be reduced (Fmlink, 2010). **High performance Landscape or Infrastructure Landscape** concept is used to maximize the performance of green infrastructure systems. Use of appropriate landscape is one of the strategies for water conservation. Xeriscaping, mulching, soil improvement, shading, site design with permeable materials and native planting are the ways of water conservation. Integrating appropriate landscape planning techniques into the project design is the most effective way of minimize surface and groundwater contamination from stormwater (Cabmphondbooks, 2009).

Xeriscaping aims to conserve water and protects the environment. They are adaptable to local conditions and drought tolerant. The principles of Xeriscape are, appropriate choice of plants, soil analysis which may include the use of solid waste compost, efficient irrigation, practical use of turf, appropriate use of mulches and proper maintenance. They provide benefits of reduction of pollutant load and reduction of water consumption. Also, Native Planting is an approach to landscaping that uses naturally grown plants. If native plants grow under local conditions, they don't need support. Mulching is very beneficial for plants because mulches are protective cover that help to maintain moisture on soil by blocking evaporation and keep the soil cooler to reduce water consumption, reduce erosion, provide nutrients and suppress weed growth. Shading is also used for water conservation to reduce moisture loss by keeping surfaces cooler. On the other hand, irrigation of the plants is very important to protect the quantity of water. Water requirements of the plants are changing according to the seasons so rain sensors can help to conserve water. Use of efficient irrigation systems such as drip irrigation or sprinkler reduce the water consumption (Tuna, 2006).

3.6. Grey Water Systems

Grey water refers to wastewater from clothes washer, showers, bathtubs and lavatory faucets not water from toilets, kitchen sinks and dishwashers. Greywater is collected with separate drain lines then filtered to remove large particles and stored until use for landscape irrigation (Environmental Building News, 2010). In present, greywater recycling is part of the water management because they promote the preservation of the potable water and reduce pollutants in environment. Reuse of domestic greywater for landscape irrigation provide significant contribution to decrease

the potable water reduction. Grey water reuse offer an opportunity due to water scarcity and rain fluctuations in arid and semi-arid regions (Al-Jayyousi, 2003).

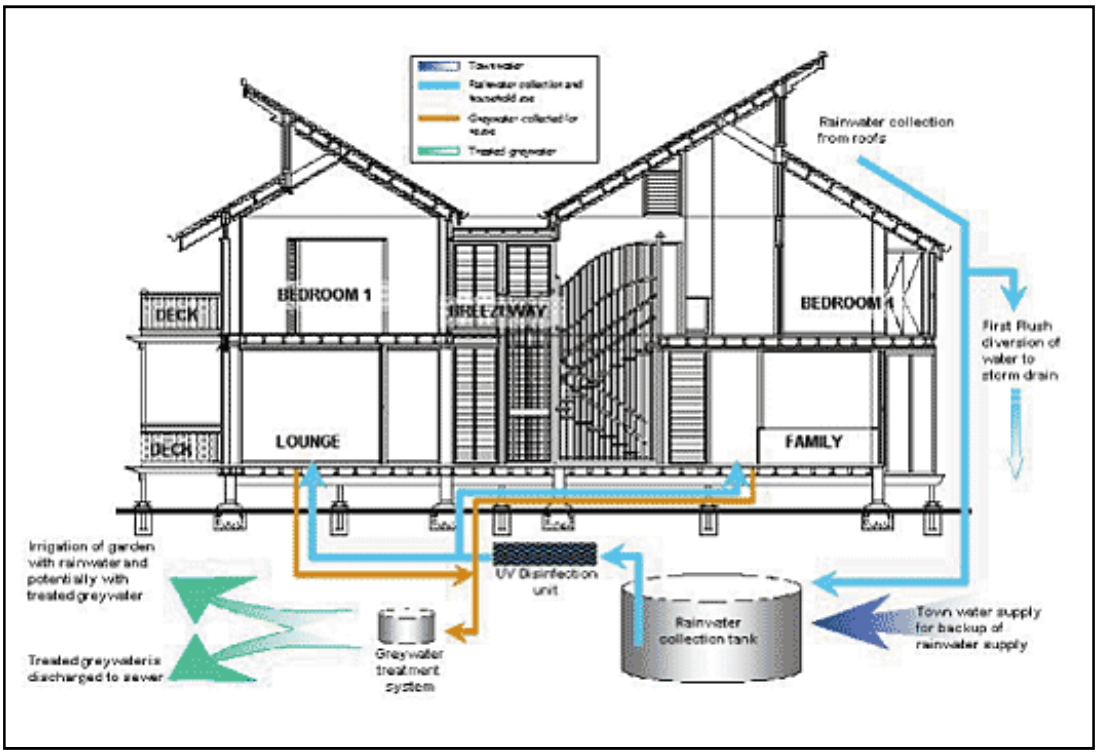


Figure 3.64. Grey Water System
(Source: Yourhome, 2011)

3.7. Stormwater Management Techniques Application Areas

Stormwater Management Techniques can be applied for many areas and the techniques can be changed according to the application area. Residential Areas, Row Houses and Mixed Use areas are some of the application examples.

Residential Areas: In residential areas for semi-detached house (Figure 3.65) with traditional development, stormwater drained to piped system but on-site stormwater approach the rainwater hold from the rooftops drained to infiltration planter boxes and there is a vegetated infiltration basin. Locally collected stormwater drained to basin for infiltration and recharge groundwater.

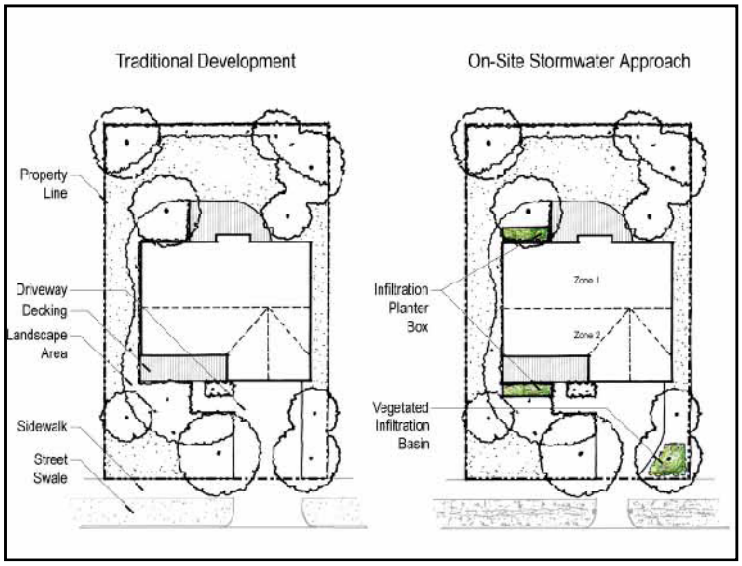


Figure 3.65. Semi-detached House Application
(Source: Brgov, 2010)

Row Houses: The residential area with row houses have flat roofs on traditional development. The rainwater on the rooftops drained to impervious surface, but at on-site stormwater approach flat roofs turned to greenroof so rainwater is hold and helps to prevent stormwater runoff. On the other hand, paved surfaces changed with porous pavement with aim of reducing stormwater runoff and providing infiltration and grounwater recharge.

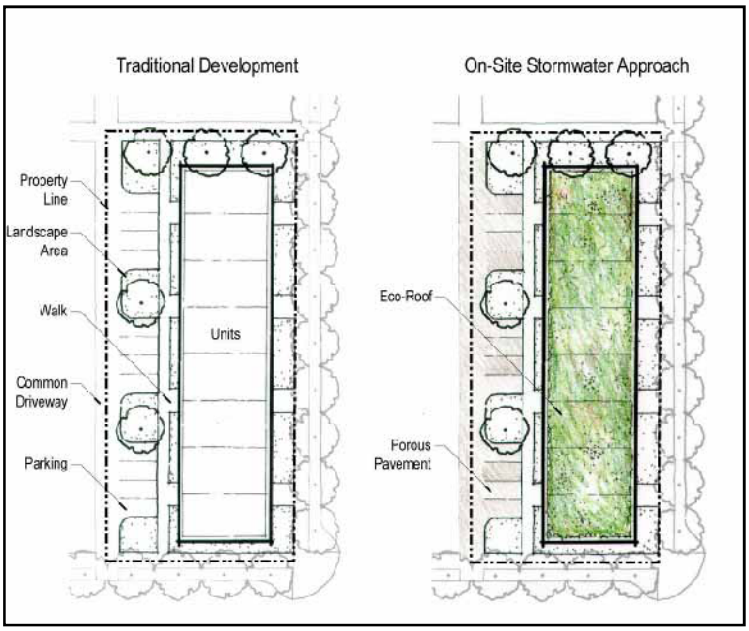


Figure 3.66. Row Houses Application
(Source: Brgov, 2010)

Mixed Use: In mixed use areas, with traditional development stormwater runoff occurs from paved surfaces of parking area and rooftops without downspout disconnection, but in on-site stormwater approach stormwater drains by natural drainage systems with the help of drainage elements like planter boxes and vegetated swale. Planter boxes are for rooftop downspout connections. The rainwater hold with downspouts drained to planter boxes, they have a filtration and groundwater recharge function. Swales are added to parking lot to lower the quantity of runoff and help to drain stormwater.

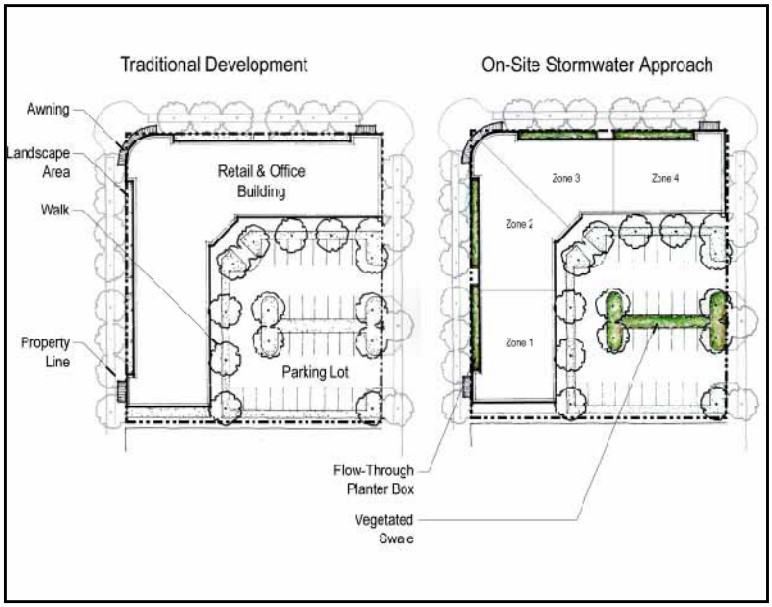


Figure 3.67. Mix Use Area Application
(Source: Brgov, 2010)

3.8. Limitations

There are some considerations when applying the Best Management Practices. A variety of factors can affect the practices. These factors are; Landuse, Physical Feasibility Factors, Watershed Factors, Stormwater Management Control Capability, Pollutant Removal Capability and Environmental and Maintenance Considerations. Firstly, **Landuse** is important because all practices can not be suitable for all landuse types, for example infiltration can not be applied to where runoff contains much dissolved constituents. Then, **Physical Feasibility Factor** affects the type of application, because soil, drainage area, depth to water table or slope are changing on sites. **Watershed Factor** is considered because runoff can be drained to watersheds.

This can affect the watershed habitat. Another one is **Stormwater Management Control Capability**. This factor specifies the capacity of practices to meet the needs. Some practices such as filtering can provide small scale water treatment not large storms. Other factor is **Pollutant Removal Capability**. This factor measures the pollutant removal capacity of practices and shows practices have different removal ability. The last factor is **Environmental and Maintenance Considerations**. The factor specifies the environmental impacts of practices. So considering the limits before application and choosing the best practice can give us best solutions.

3.9. Summary and Evaluation

As a result, chapter three firstly, highlights the water management approaches all around the world from history to present. It is mentioned that the approaches are similar in the past and present but their definitions are changing and both of them have the same aim of protecting water resources. For providing this, some water management techniques are developed to be more sustainable for environment. These techniques include stormwater drainage and basin techniques, greywater system, green street design, efficient landscape techniques, pervious paving and green parking techniques, and these techniques are explained with detailed drawings and figures and the application areas are specified. Lastly, limitations are mentioned for the practices and the factors that affect the design are explained briefly.

CHAPTER 4

SUSTAINABLE CAMPUS WATER MANAGEMENT APPLICATIONS

In chapter four, sustainable campus water management applications are defined with campus examples around the world according to climatic zones. Which strategies are developed by university campuses and what are their Best Management Practices for stormwater management are specified. Lastly, University of North Carolina, University of Wisconsin Milwaukee, Portland State University and Georgia Institute of Technology water management strategies and Best Management Strategies are analyzed in detail.

With the increasing environmental problems, a concept of sustainability arises in the campus master plans. They create design guidelines to protect the environment because they realize the increasing environmental effects as the campuses developed and scattered. These design guidelines are for landuse, transportation, site, landscape, **water**, energy, materials and resources and indoor environmental quality. Among these categories, water is studied and analyzed in detail. Water resources are important for the future so most of the universities take precautions to reduce the water consumption and have water management programs. These programs include stormwater management strategies, greywater systems and irrigation techniques. Both of them aim to reduce the consumption of potable water and protect the groundwater recharges. Water is not a renewable source, as we consume, it will decrease and in the future water wars are expected to occur worldwide. Around the world, most of the university campuses specify the importance of water management in their plans. Some of them define their water management strategies in their landscape master plans like Georgia Technical University and some of them has stormwater master plans like University of Wisconsin Milwaukee that include analysis, stormwater techniques and demonstration projects; and others have stormwater management plans that include analysis, design guidelines, techniques and best management practices like University of North Carolina.

Campus Water Management applications change according to site, topography, soil type, climatic conditions and natural resources (Table 4.2). Quantity of rain fall is

an essential data for the techniques to be implemented that are used for water harvesting and this ratio changes in different climatic zones. There are seven type climatic zones: Type A (Tropical Humid), Type B (Dry, Arid or Semiarid), Type C (Humid Subtropical, Mediterranean and Marine West Coast), Type D (Humid Continental) and Type E and H (Polar) (Figure 4.1). All of them have different rain fall capacity. The Table 4.1 below shows the universities' climatic zones which given as an example for water management applications. There are four climatic zones. These zones are **Humid Subtropical Climate** zone characterized by hot humid summers and cool winters, **Humid Continental Climate** zones are characterized by warm to hot often humid summers and cold winters, **Mediterranean Climate** zones are characterized by warm to hot dry summers and mild to cool wet winters and **Arid Climate** are characterized by high evaporation and low precipitation.

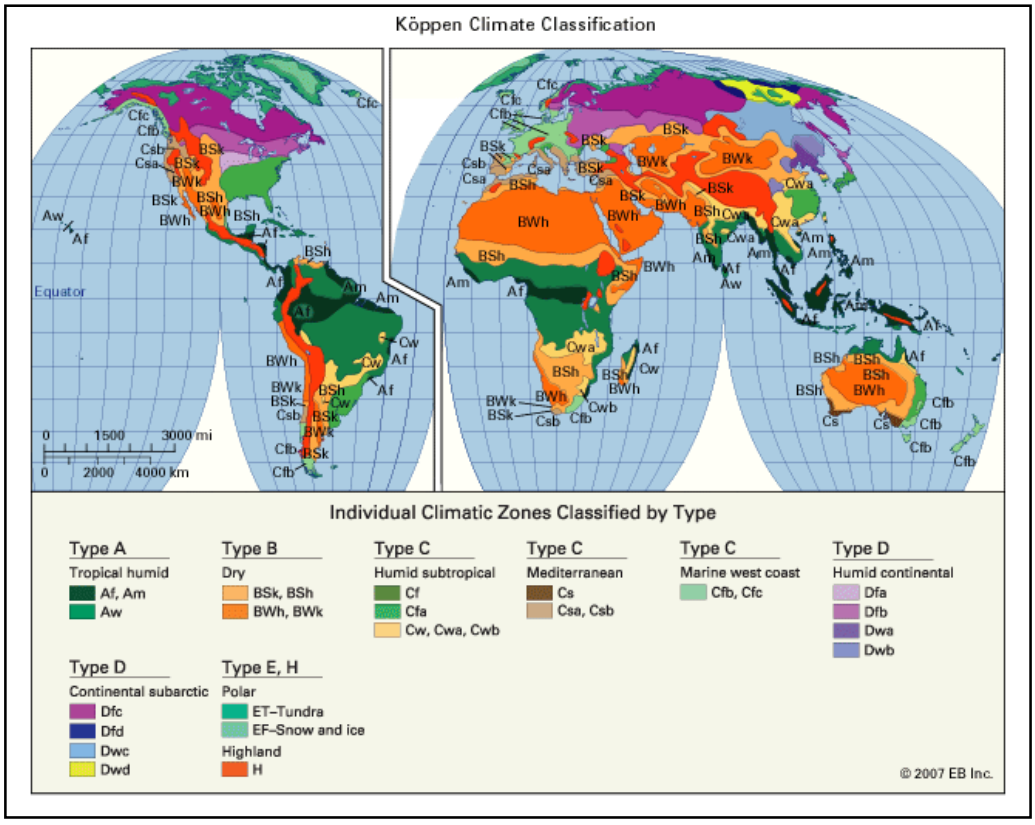


Figure 4.1. World Map of Köppen Climate Classification
(Source: Britannica, 2011)

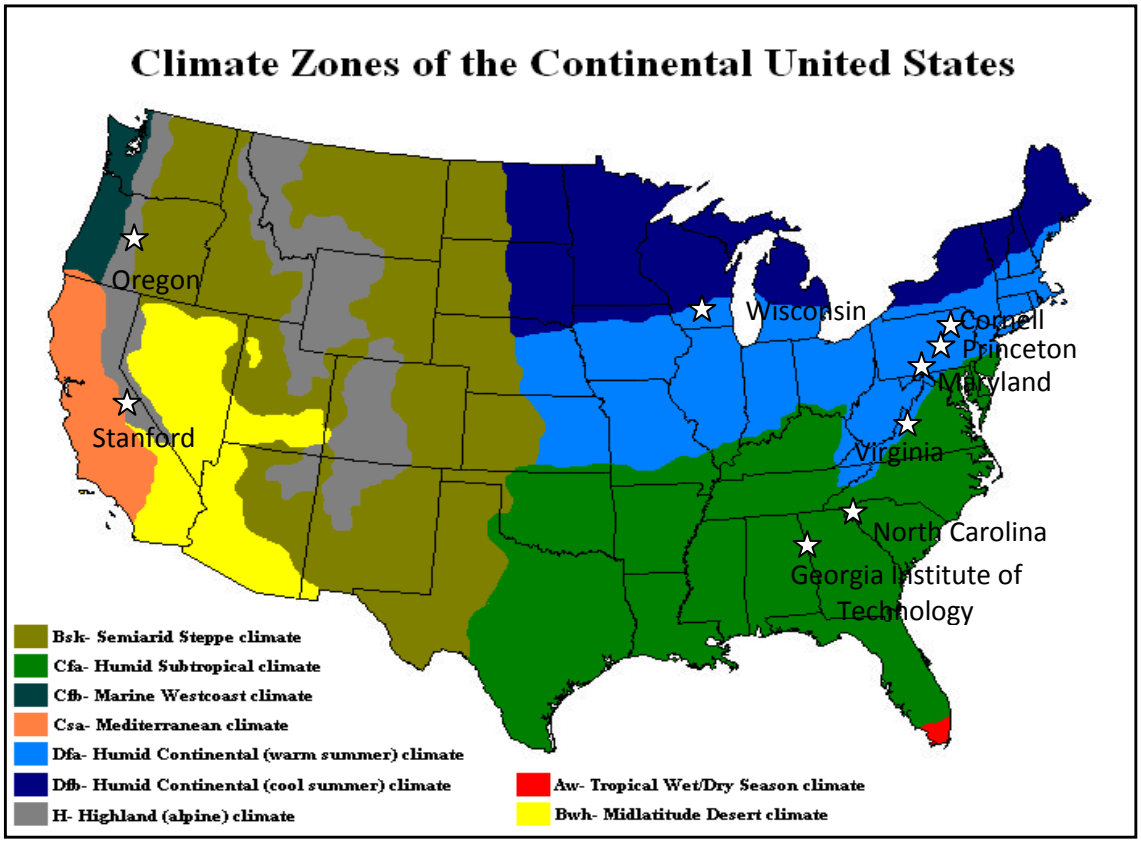


Figure 4.2. Climatic Zones of the North U.S.A.
(Source: Wikipedia, 2011)

Table 4.1. Climatic Zones of the Sustainable University Campuses

Climatic Zones	**Humid Subtropical Climate**	**Mediterranean Climate**	**Arid Climate**	**Humid Continental Climate**
Universities	Virginia Univ. North Carolina Univ. Victoria Univ. Princeton Univ. Nottingham Univ. Maryland Univ.	Stanford Univ. Portland Univ. Oregon Univ.	King Abdullah Univ. Arizona Univ. Arizona State Univ.	Cornell Univ. Michigan Univ. Wisconsin Univ. Milwaukee Univ.

Table 4.2. Sustainable Universities Water Management Applications

Universities	**Water Management Applications**
Stanford University (Stanford, California, U.S.A.)	Stormwater Management: • Use biologically based stormwater management features such as swales, sediment control ponds, pools, wetlands along drainage courses, and infiltration basins to retain and treat stormwater on site and/or in adjacent areas. • Maximize pervious and vegetated areas of the site Erosion Control: • Prevent soil erosion before, during, and after construction by controlling stormwater runoff and wind erosion. • Silt fencing, sediment traps, construction phasing, stabilization of slopes, and maintaining and enhancing vegetation and groundcover. Gray water systems
University of Arizona (Tucson, Arizona, U.S.A.)	Surface Water Master Implementation Plan: • Reduce runoff throughout campus • Keep surface water on campus • Conserve water • Support sustainable landscape
University of Virginia (Charlottesville, Virginia, U.S.A.)	Stormwater Master Plan: • Creating wetlands • Creating ponds • Planting native wetland species • Creating floodplains • Creating vegetated buffers • Enhanced Infiltration • Detention Basins • Permeable parking spaces

(Cont. on next page)

Table 4.2. (Cont.)

University of North Carolina (Chapel Hill, North Carolina, U.S.A.)	Stormwater Management: • UNC- The Bell Tower stormwater detention roof water cistern and non-potable water system (project combines stormwater, reclaimed water, and asset management in sustainable initiatives) • Water Management Program and Plan
Portland State University (Portland, Oregon, U.S.A.)	Stormwater Management Plan: • Decrease Impervious Surfaces • Improve water quality • Decrease water runoff peak rate • Improve natural habitat • Reuse stormwater on site • Pest management plan • Best Management Practices
University of Oregon (Eugene, Oregon, U.S.A.)	Stormwater Management: • Focus on filtering runoff resulting from rainfall events that are equal to or less than 1”(about 80% of all rainfall events in Eugene). • Use plant materials and terrain to slow and absorb runoff, filter sediments, and facilitate infiltration. • Maximize pervious surfaces to permit water infiltration. • Use natural drainage ways.
Princeton University (Princeton, U.S.A.)	Stormwater Master Plan: • Reduce storm water runoff through on-site mitigation techniques such as rain gardens or green roofs • Install rainwater storage and reuse systems in new construction projects and major renovations when possible. • Minimize irrigation through the use of drought resistant plantings and properly selected soils. • Reduce the total square footage of impervious surface area on campus by building structured parking facilities.

(Cont. on next page)

Table 4.2. (Cont.)

Georgia Tech University (Atlanta, Georgia, U.S.A.)	Stormwater Management Plan: (Storm water collection and reuse: cisterns, towers, ponds, and the "Eco-commons") • Develop the Eco-Commons and associated Corridors into a sustainable stormwater management system. • Replace existing management systems which funnel storm-water into pipes, with systems that bring water into contact with the soil. • Reconstruct and condition soils to increase infiltration and storage. • Recharge groundwater supplies and reinvigorate pre-existing natural drainage systems of the campus. • Increase campus tree canopy coverage. • Increase the campus coverage of woodlands.
University of Wisconsin-Milwaukee (Milwaukee, Wisconsin, U.S.A.)	Campus Stormwater Management Plan • Computer Stormwater Management Model • Efficient Landscape to improve water quality • Green roofs • Rain gardens and Bio-swales throughout campus • Pervious surfaces • Best Management Practices
Purdue University (Indiana, U.S.A.)	Stormwater Master Plan: • Increase the awareness of rainfall as a water supply • Prevent groundwater pollution • Sustainable approach to manage stormwater runoff • Provide healthy soil and efficient vegetation • Application of Stormwater Best Management Practices

(Cont. on next page)

Table 4.2. (Cont.)

Rutgers University (Newark, New Jersey, U.S.A.)	Stormwater and Landscape Management Master Plan: • Best Management Practices • Functional Landscape • Bioswales, rooftop vegetation • Rainwater Harvesting • Underground Filters • Underground detentions • Ponds, Wetlands • Permeable Pavements • Stream Restoration
King Abdullah University of Science andTechnology (KAUST) (Thuwal, Saudi Arabia)	Stormwater Management Plan: • Rainwater will be harvested and stored for use, and – to protect its natural ecosystems and recreational facilities. • KAUST will utilize landscaping that does not require supplemental irrigation. Reduce the use of clean water: • Efficient water fixtures and waterless urinals • Native and adaptive species have been selected for a majority of the plantings
University of Victoria (Toronto, Canada)	Integrated Stormwater Management Plan(ISWMP): • Limiting use of fertilizers and pesticides • Maintaining open spaces • Protecting stream beds • Minimizing construction-related vegetation removal • Ensuring timely replanting of building sites • Minimizing the overall extent of impervious surface (such as parking lots) and building area. • Utilize natural/naturalized systems to manage stormwater: (e.g. sediment control ponds, retention ponds, bio-swales, etc.)

4.1. University of North Carolina, Chapell Hill

University developed a Carolina Environmental Program and focuses on environmental learning, research and public service in 1998 and developed some criteria at some categories. These categories consist of transportation, water management, landscape, energy, recycling and building and material.



Figure 4.3. University of North Carolina Site Plan
(Source: UNC-3, 2010)

University has a Water Management Plan which is prepared in 2004 aims to support the comprehensive planning effort of the eight year development plan. The objectives of the program are to preserve the natural drainage system, to preserve stream corridors and forested steep slopes, to protect water quality, to maximize on-site infiltration of stormwater to recharge groundwater, to capture and reuse of rainwater, to enhance and protect the water quality of the surface streams to meet National Pollutant Discharge Elimination System water quality standards, and last to plan mapping the major pipes of the whole campus, analyzing the stormwater quality and quantity impacts on existing campus and quantified for each of the watersheds of campus streams, analyzing the stormwater quality and quantity for the eight-year development program and understanding and correcting the potential for flooding in the 10 year and the 100 year storms. The Plan consists of Stormwater Management Program that include best management practices to improve water quality and quantity. Program manages stormwater as an opportunity not a problem. Program aims to maximize present and future on-site infiltration of stormwater to recharge groundwater and capture and reuse of stormwater. Best Management Practices proposed for The University of North Carolina are both structural and non-structural. Structurals are; storage and infiltration beds in open spaces, pervious paving, rain gardens, continues tree trenches, runoff capture and reuse systems and water quality inlets. Non-structurals are; reduction of lawn, conversion of woodland to layered forest, conversion of grass areas to meadow, pest management programs and education programs.

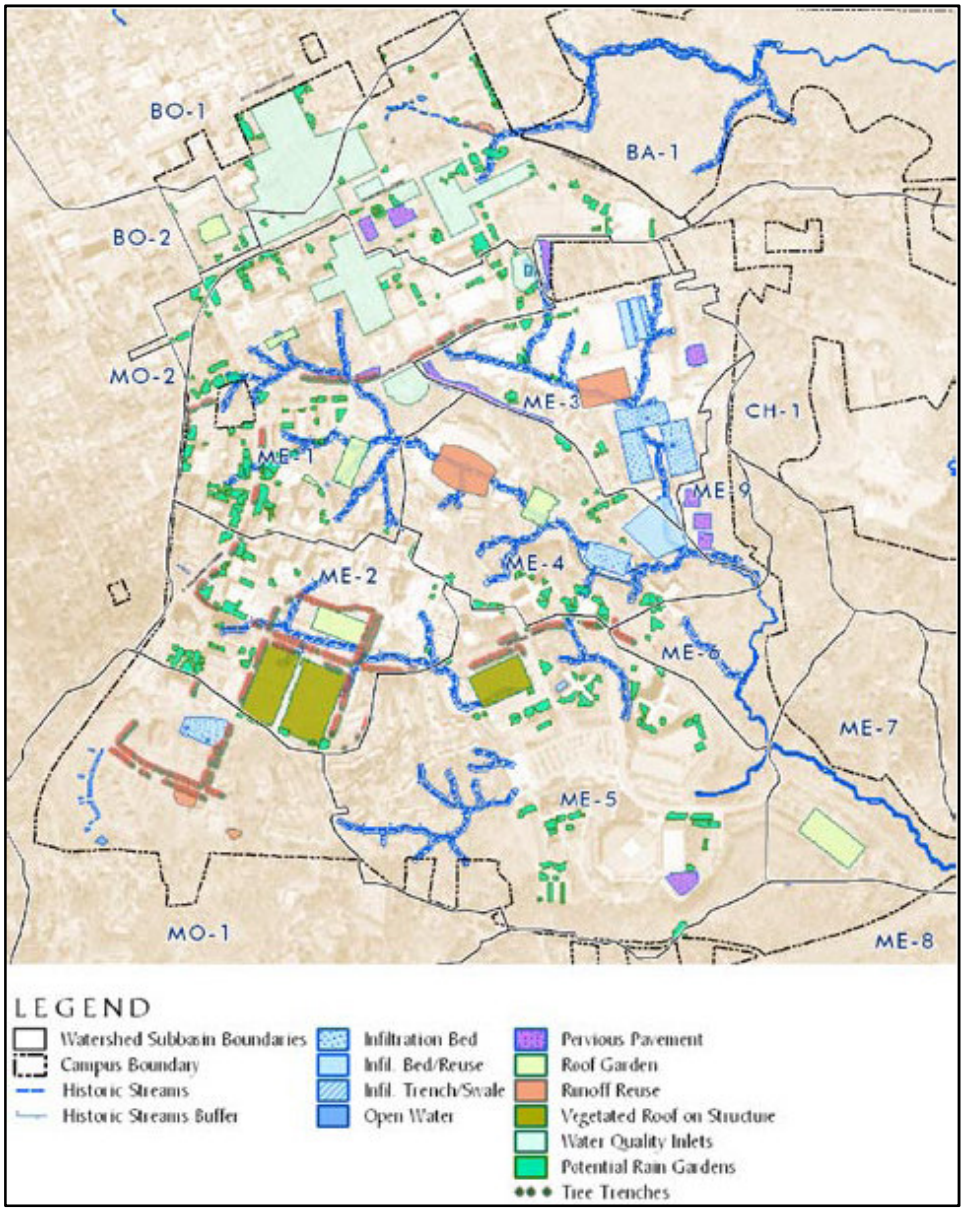


Figure 4.4. Proposed All Best Management Practice Locations on UNC Hill Campus (Source: UNC-1, 2009)

UNC has 3 BMP Projects. These are Science Complex, Bell Tower Complex and Global Education Center. Science Complex will provide the storage function with a form of green roof, vertical storage, cisterns and underground pipes with the 200.000 cubic feet recommended capacity. In the Bell Tower Complex, the impervious surface parking area is turned to proposed new Genome Science Building. Rainwater that will fall on the roof the Genome Science Building will be stored in a cistern that can able to store up to 350.000 gallons of water (Figure 4.6). Global Education center has vegetated roof and the design of the building is proper for two underground stormwater storage

structures that one of is served as a cistern to supply water for flushing toilets in the building (Figure 4.5).



Figure 4.5. Global Education Center Green Roof
(Source: UNC-2, 2009)

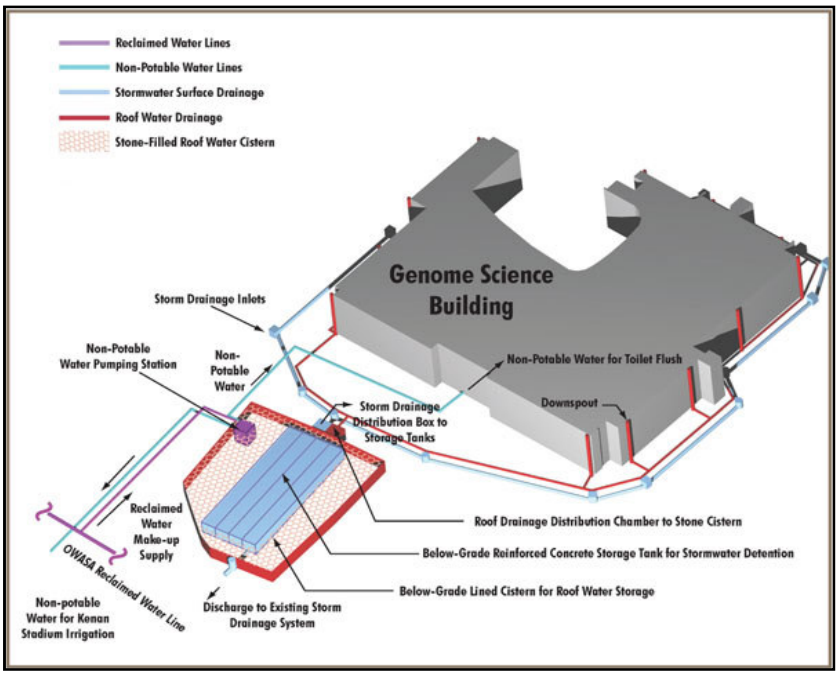


Figure 4.6. Bell Tower Complex
(Source: UNC-2, 2009)

On the other hand, university has stormwater system applications. Firstly, campus has number of porous pavement parking lots that have under storage beds. Permeable pavements are used for existing Estes Drive Remote Lot which has 600 car capacity and 750 car parking lot near to the Friday Center at the South of the campus (Figure 4.7).

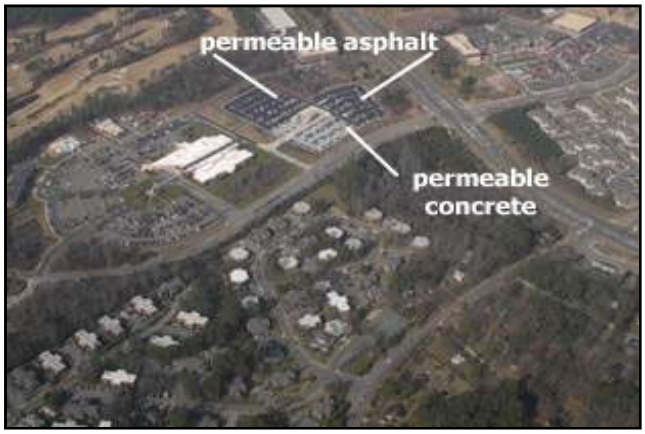


Figure 4.7. Friday Center Lot
(Source: UNC-2, 2009)

In these areas permeable asphalt and permeable concrete were used. Soil type at the Friday Center is clay so lot has deeper bed. Upper layer of clay soil is removed in some parts. Besides parking lots, some parts of the campus are suitable for the construction the storage and infiltration beds to hold and infiltrate stormwater. These areas are; Athletic Fields, Intermural Play Fields and Recreational Areas. Most of the building at campus has green roof like Rams Head Center (Figure 4.8).

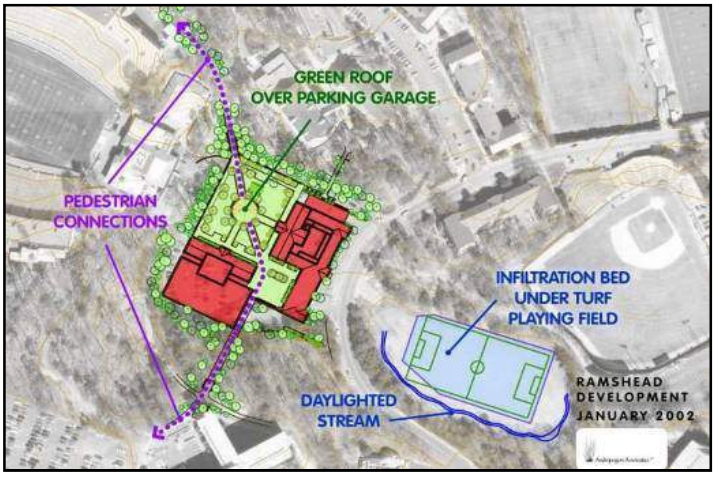


Figure 4.8. Rams Head Center
(Source: UNC-2, 2009)

In the Rams Head Center Plan, the areas shown yellow are the places for storage tanks. Under the walking area around the building capture the stormwater from the roof of the building.

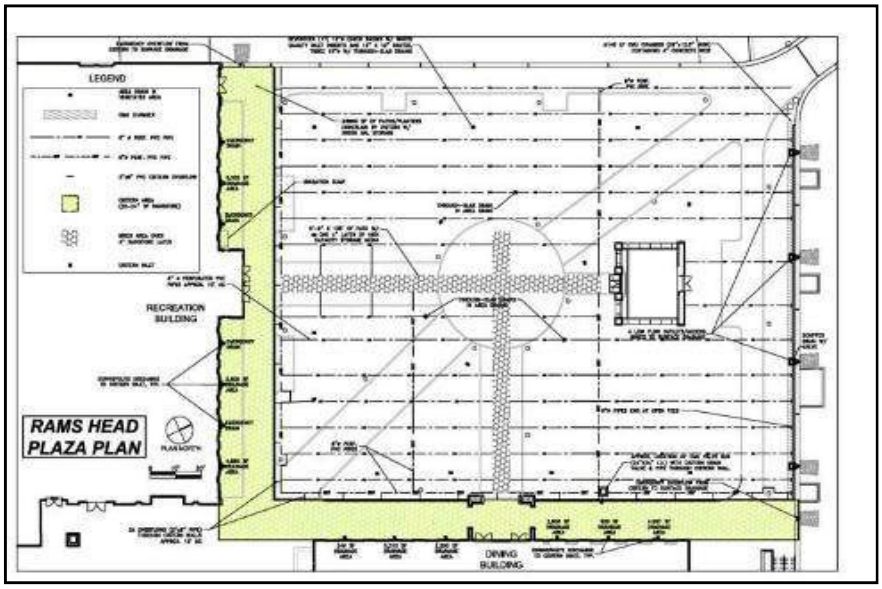


Figure 4.9. Rams Head Center Plan
(Source: UNC-2, 2009)



Figure 4.10. Rams Head Center
(Source: UNC-2, 2009)



Figure 4.11. Rams Head Center Storage System Construction
(Source: UNC-2, 2009)



Figure 4.12. Rams Head Center Rainwater Drainage from Roof
(Source: UNC-2, 2009)

Rainwater collected from the roofs stored in cisterns. Carmichael Field practice is one of the examples for storage systems from the roofs (Figure 4.13, 4.14). Also, there are water quality inlets to control the pollutants of water and vegetated swales are used as natural infiltration element for stormwater.

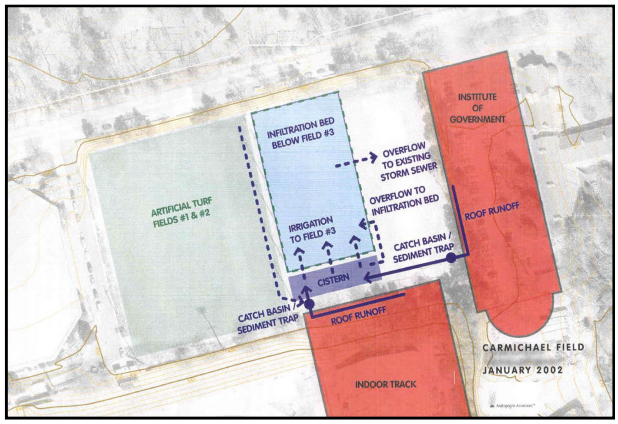


Figure 4.13. Carmichael Field
(Source: UNC-2, 2009)



Figure 4.14. Carmichael Field
(Source: UNC-2, 2009)

The capacity of the soils to infiltrate is important for BMPs. When the soil was analyzed for the campus, it showed that soil is categorized as moderately well drained, but although the soils at UNC-Chapel Hill have a high clay content, infiltration occurs in some locations even if very slowly. (Andropogon Associates, Cahill Associates, The Rose Group, 2004).University has water Project that provide cooling tower make up water for the University's chilled water plants for the largest water use in campus and athletic field irrigation. Also, efficient fixtures and systems are used to reduce demand for potable water. Also, proper landscape planning has a supportive effect to stormwater management. University has some strategies about water efficient landscaping, so all landscapes are planned with appropriate native and non-invasive species that support low maintenance, low water use, and low fertilizer use and the total amount of tree canopy coverage will increase in campus (UNC Sustainability Office, 2009).

4.2. University of Wisconsin- Milwaukee

University of Wisconsin-Milwaukee define their campus as a “zero discharge zone” and aim to investigate stormwater and apply demonstration projects. The strategy of the master plan is to create an environment that has high capacity of absorb and store the water. The Stormwater Master Plan which is prepared in 2006 for UWM Campus defines the parameters of the zero discharge and physical applications for the campus. The plan includes the computer Stormwater Management Model (SWMM). Stormwater Management Model was developed by a master of engineering student. Plan aims to detain stormwater above ground and utilize landscape to improve water quality, utilize greenroofs, rain gardens and bio-swales throughout the campus to decrease discharge rates to sewer system, daylight internal roof drains and transfer runoff to the rain gardens, utilize landscape to capture the rainwater from externally drained roofs and decrease impervious areas. Campus has two drainage areas. 25 ha of campus drain to the North and 15 ha of campus drain to the South. North drainage area has % 48 impervious surfaces but the South drainage area has %73 impervious surface. The campus divided into 21 catchment areas. Campus has Best Management Practices for stormwater management. Firstly, campus has Green Roof Projects. Sanburg Residence Hall, Golda Meir Library, UWM Union, Union Entry, Spaights Plaza Pavilions and Central Power Plant are some of the internally drained green roof projects (Figure 4.16, 4.18, 4.20, 4.22).



Figure 4.15. Sandburg Residence Hall Roof (Present)
(Source: UWM Final Report, 2006)

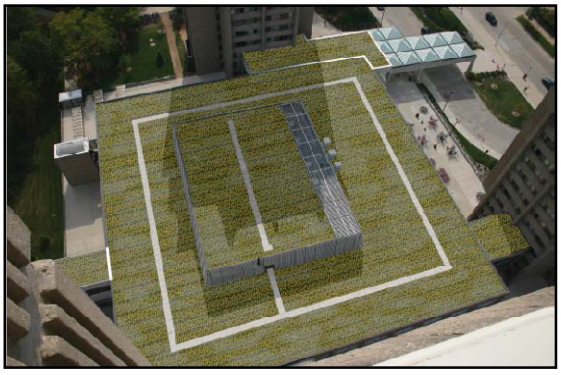


Figure 4.16. Sandburg Residence Hall Green Roof (Future)
(Source: UWM Final Report, 2006)



Figure 4.17. Golda Meir Library (Present)
(Source: UWM Final Report, 2006)



Figure 4.18. Golda Meir Library Green Roof (Future)
(Source: UWM Final Report, 2006)



Figure 4.19. UWM Union (Present)
(Source: UWM Final Report, 2006)



Figure 4.20. UWM Union Green Roof (Future)
(Source: UWM Final Report, 2006)



Figure 4.21. Union Entry (Present)
(Source: UWM Final Report, 2006)



Figure 4.22. Union Entry Green Roof (Future)
(Source: UWM Final Report, 2006)

On the otherhand, Greene, Johnstone, Merrill, Chapman and Curtin Halls are the externally drained roof examples (Figure 4.23 to 4.26). Externally drained roofs, drained rainwater from the roofs via downspouts through rain gardens to infiltrate and capture.



Figure 4.23. Merrill Hall Downspout
(Source: UWM Final Report, 2006)



Figure 4.24. Proposed Rain Garden Connected with Downspout
(Source: UWM Final Report, 2006)



Figure 4.25. Chapman Hall Proposed Rain Garden
(Source: UWM Final Report, 2006)



Figure 4.26. Curtin Hall Proposed Rain Garden
(Source: UWM Final Report, 2006)

Also, permeable paving strategy is developed. Aim is reducing the hardscape surfaces so permeable concrete or paving stone are preferred to allow the stormwater infiltration and groundwater recharge, but the campus soil type is clay so it requires excavation and creation a drainage layer. In some parts of the campus area, basins are created to hold the stormwater from hardscape areas. Pocket Wetlands or Stormwater Planters (Figure 4.27 and 4.28) are some of them. Besides them, bioretention swales are recommended in parking areas.



Figure 4.27. Proposed Stormwater Planter
(Source: UWM Final Report, 2006)



Figure 4.28. Proposed Stormwater Pocket Wetland
(Source: UWM Final Report, 2006)

Dayligthing water is an another strategy. The aim of the strategy is bring water back into experienced environment where it can serve ecological and aesthetic function at all scales. Pavilion Gateway Demonstration Project have applications about the strategies (Figure 4.31). In the Project, Pavilion Gateway Path is not only links the new pavilion parking structure and core of the campus, it creates drainage axis. The drained stormwater is collected in spiral garden basin (Figure 4.29 and 4.30).



Figure 4.29. Spiral Garden Basin
(Source: UWM Final Report, 2006)



Figure 4.30. Spiral Garden Basin
(Source: UWM Final Report, 2006)

In this project, campus has identified two parking lots. Stormwater demonstration activities are applied to these two parking lots. Two parking lots joined with a path. In both parking lots, stormwater from the hardscape areas and rainwater from roofs are drained through the path and directed to the Spiral Garden basin. Spiral Garden captured the runoff from the whole system then added to drainage system (Figure 4.31).

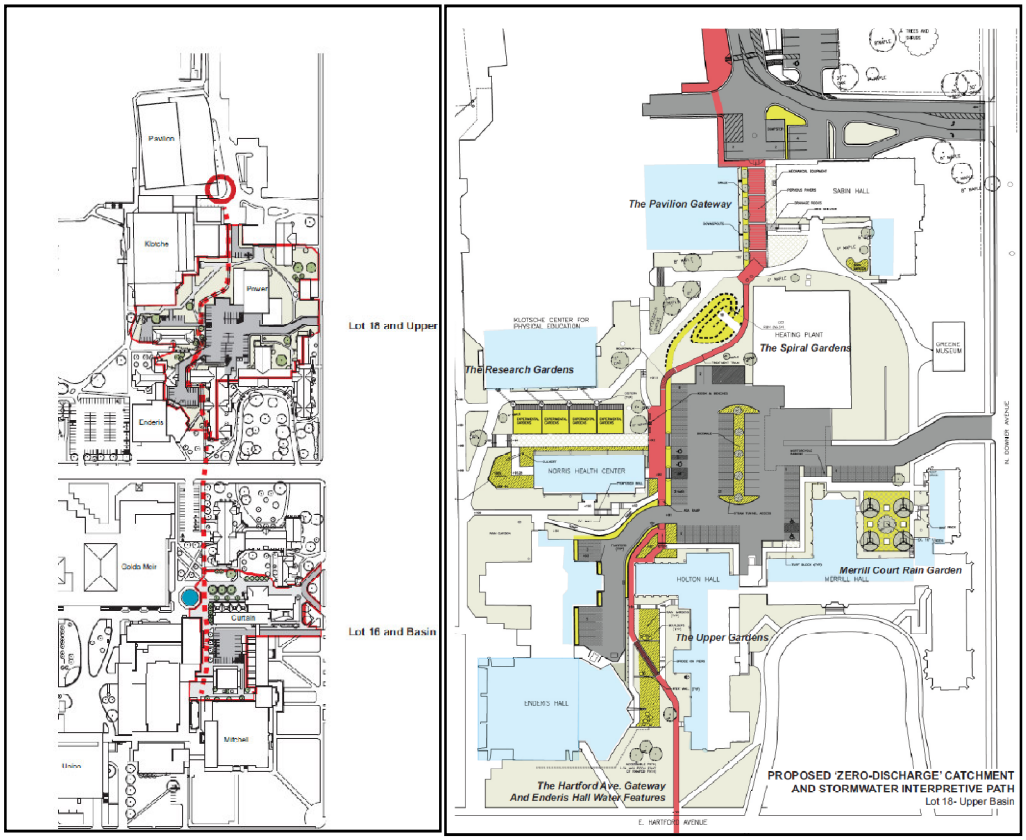


Figure 4.31. Pavilion Gateway Demonstration Project
(Source: UWM Final Report, 2006)

In project some of the impervious surfaces are turned to pervious. Internally drained roofs are daylighted and externally drained roofs are added to system with downspouts and directed to rain gardens. The collected water is hold above the ground and created connected water ways (Figure 4.32).

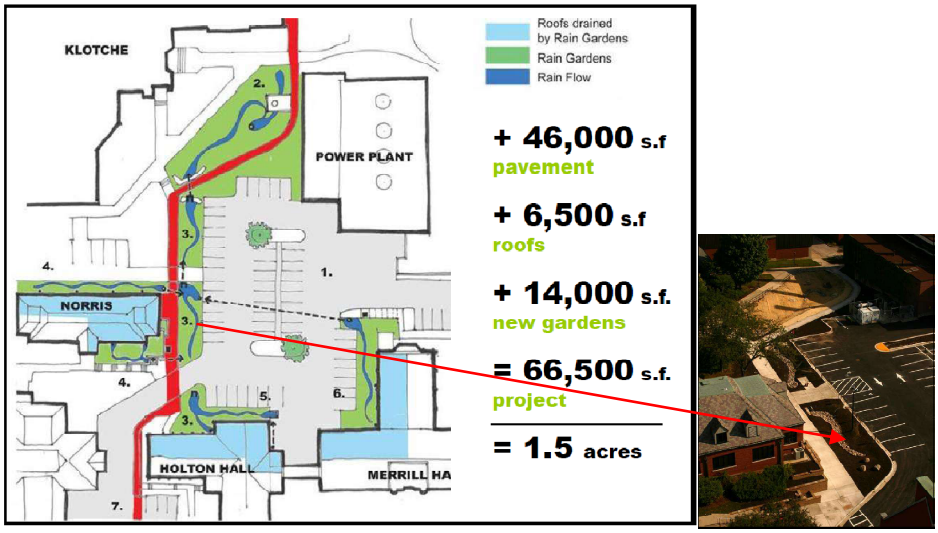


Figure 4.32. Connected Water Ways
(Source: UWM Final Report, 2006)

4.3. Portland State University

Portland State University aims to conserve and manage water at whole or local level so Portland State University Sustainability Office developed Stormwater Management Plan. University adopt stormwater management principles to their designs, implemented sustainable design into new and remodeled infrastructure and landscape. University developed some goals for stormwater management. They aim to decrease impervious surfaces, improve water quality, decrease water runoff peak rate, improve natural habitat systems, developing designs to reuse stormwater onsite, develop stormwater management plan and integrated pest management plan (PDX-1, 2010).

University developed some principles for water management. Firstly, they aim to apply water resource management at the catchment or sub-catchment level. Future developments will not have impervious surfaces. Buildings will be protected from flooding or damage by surface and groundwater also building designs will be appropriate to the water harvesting. On the other hand, they will increase the vegetation and use indigenous vegetation. Also, university takes precautions to prevent the water pollution.

University has Best Management Practice implementations which are reducing high maintenance landscape areas and implementing native landscaping, creating onsite detention areas, building new buildings with green roof, preparing stormwater

infiltration systems with existing and new buildings, designing natural drainage systems such as bioswale, constructing ponds and wetlands and using pervious paving materials. Portland State University's one of the best management practice is **Epler Hall** Rainwater Harvesting System. Epler Hall is a new student housing facility for the university and has innovative and environmental concept in order to create a healthy living space for students. The building has recently been LEED Certified by the U.S Green Building Council (PDX-2, 2010). Epler Hall is a mixed- use Silver Building that has innovative rainwater harvesting system (Figure 4.33). % 26 of Stormwater was collected from Epler Hall and the neighboring King Albert Hall (PDX-1, 2010). During rain events, water shoots down a five-story downspout into a rock-filled basin, gushes out a small scupper into a runnel that directs water across the space, then falls into a "biopaddy" {a sunken plant-filled basin) (Figure 4.34) (Turner, 2005). All of the basins are laid along a slope (to match the grade of the site), which helps water to drain into the next biopaddy via runnels during times of storm overflow. This way, the plaza stays dry (Echols and Pennypacker, 2008).

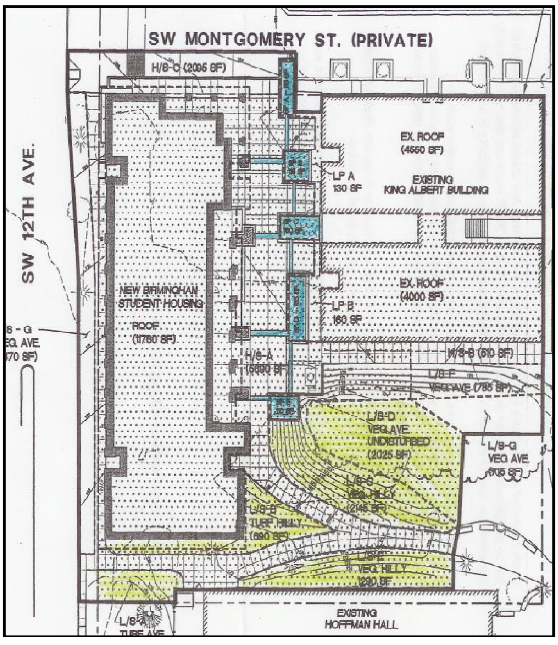


Figure 4.33. Epler Hall Stormwater Harvesting System
(Source: Prakopcyk and Staudt)

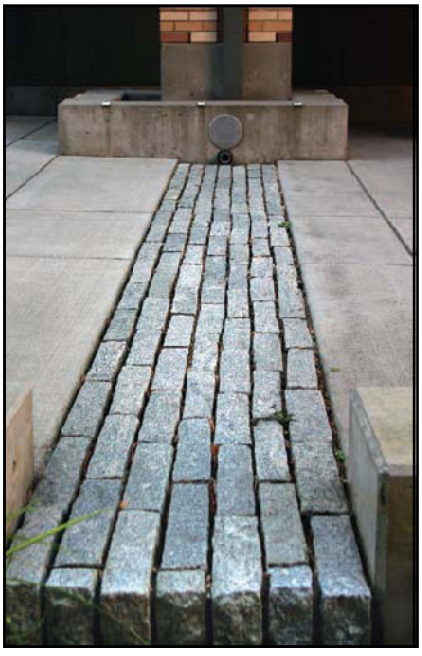


Figure 4.34. Conveyanve
(Source: Prakopcyk and Staudt)

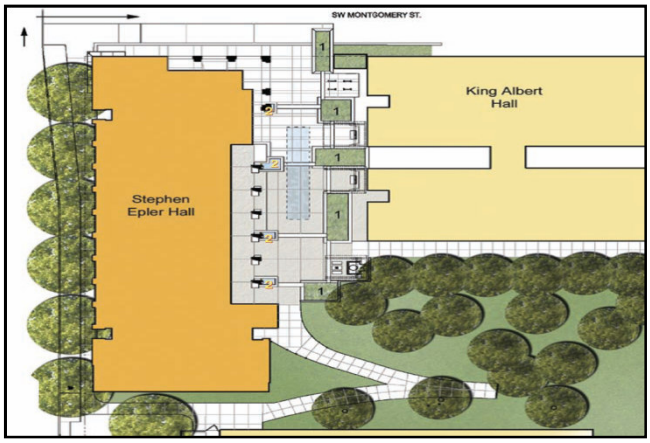


Figure 4.35. Epler Hall Stormwater Harvesting System
(Source: Padmanabhan, 2009)



Figure 4.36. Planter Box
(Source: Padmanabhan, 2009)

Another application is **Engineering Building Hydrology Lab** that have rainwater harvesting system. System collect the rainwater from rooftop of the building. The water is stored in a 1000 Gallon storage tank, filtered through carbon and undergoes UV sterilization before pumped to toilets and urinals. On the other hand, university has **12th Green Street** application (Figure 4.38 and 4.39). Planter Boxes were added to street that contains soil and wetland plants. Water that enters the boxes absorbed into the soil and taken up by the plant. The 12th Street Green Street was awarded a 2006 Professional Award of Honor by the American Society of Landscape Architects. In site plan (Figure 4.37), we can see the planter boxes that are connected to each other. When one of them is filled with surface water flow from the curbs (Figure 4.39) to the planter box, excess water flow through the other planter box (Figure 4.38) (PDX-2, 2010).

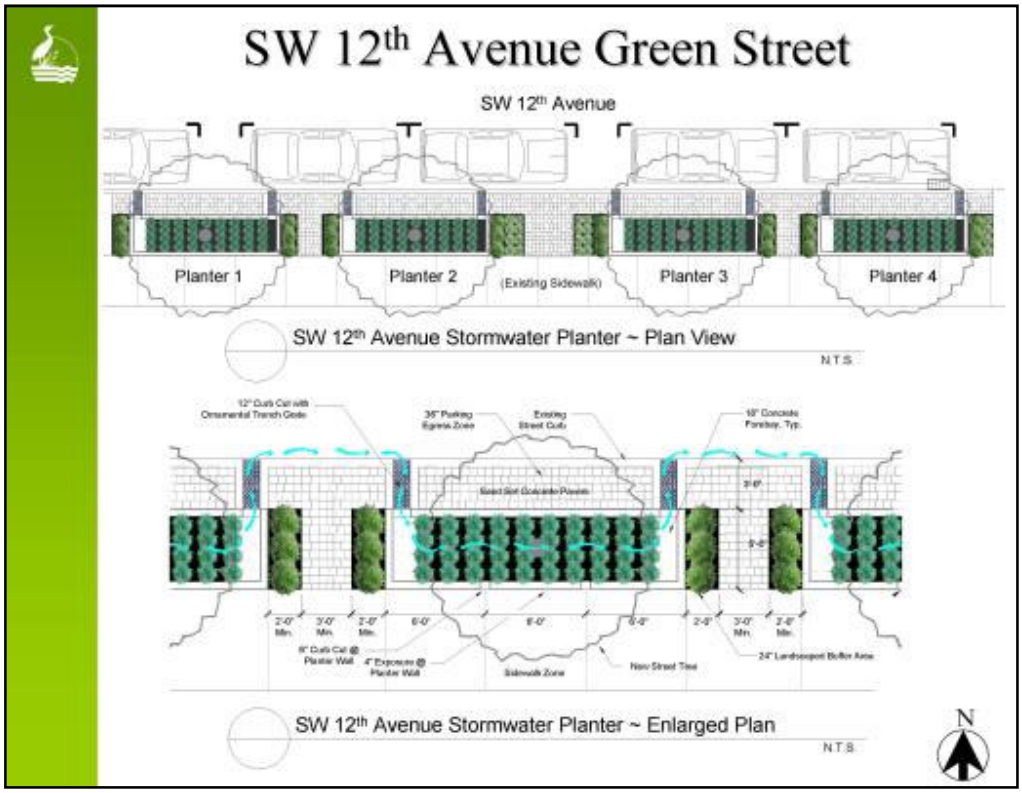


Figure 4.37. Project Site Plan
(Source: Asla-1, 2010)

.



Figure 4.38. Planter Boxes
(Source: Asla-1, 2010)



Figure 4.39. Planter Boxes
(Source: Asla-1, 2010)



Figure 4.40. Ornamental Trench Grates
(Source: Asla-1, 2010)



Figure 4.41. Curb-Cut Openings to Planter Boxes
(Source: Asla-1, 2010)

Another practice is green roof. Portland State University has five green roof applications. University is awarded for 2005 Best Award for the Broadway Housing Building's green roof.



Figure 4.42. Green Roof
(Source: PDX-1, 2010)

All landscape designs are prepared proper to stormwater plan. Native plants are used also less water demand plants are preferred to reduce water consumption. University use centralized control system for irrigation. This system control the water consumption and soil water content to reduce the irrigation.

4.4. Georgia Institute of Technology

Georgia Institute of Technology has an aim of providing the sustainable future and quality of life to students and academicians with scientific and technological knowledge base and innovation in their strategic plan. University developed Landscape Master Plan with an aim of water harvesting and reuse, protecting water quality and providing groundwater recharge.

Before campus settlement, the area occupied by Georgia Institute of Technology was covered with forests and pastoral landscape, but with the development of campus most of the area was covered with buildings and pavers. Year by year, there is more stormwater runoff, less vegetation, less biological diversity. To prevent these, Georgia Institute of Technology developed a Landscape Master Plan. The aim of the landscape plan is to develop an integrated, ecologically-based landscape and open space systems to achieve the university's goal of environmental sustainability. Landscape plan has objectives in four categories. These categories are; energy and atmosphere, water, vegetation and human design. The objectives for water and vegetation are; reduce stormwater discharge to the sewer system by % 50, improve surface water quality, reduce consumption of potable water for non-potable uses, harvest stormwater for non-potable uses such as irrigation, increase campus tree cover, reduce lawn areas, increase campus coverage by woodlands and increase biodiversity. Landscape plan consists of stormwater management techniques which are observe and mimic the pathway of rainfall in a natural environment, alternative stormwater transport methods such as use gravel-filled trenches along pathways, irregular surface swales, small scale surface detentions, subsurface retention and infiltration, green building concept and use of cisterns and storage. To demonstrate the techniques Plan consist Eco-Commons Project to reduce the stormwater runoff (Figure 4.43) (Gatech, 2010).



Figure 4.43. Map of Eco-Commons
(Source: Gatech, 2010)

Eco-Commons are the one of the ecological performance zones for the entire campus that provide the requirements of the stormwater runoff, impervious areas, tree canopy coverage and woodland area (Figure 4.45).

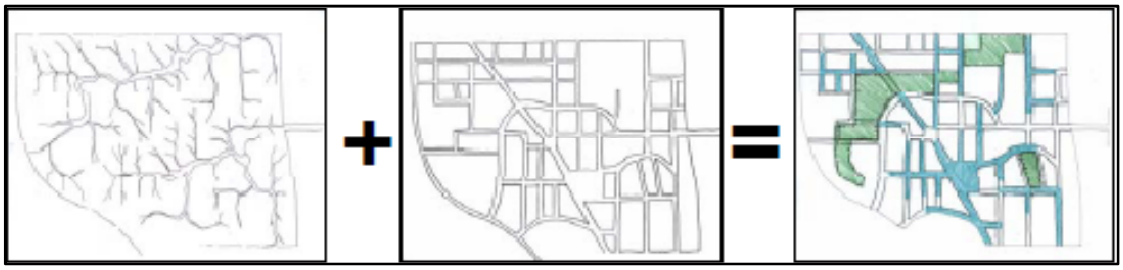


Figure 4.44. Drainage Pattern by the Grid of Street Corridors
(Source: Gatech, 2010)

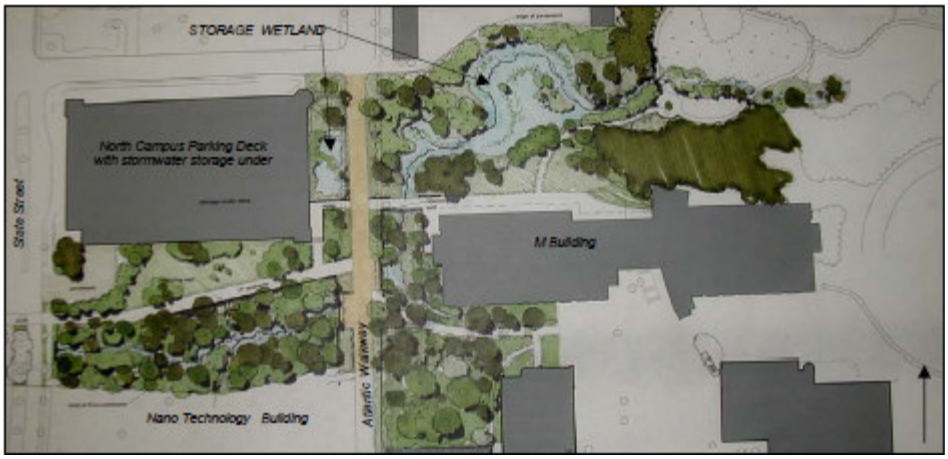


Figure 4.45. Concept Plan of Eco-Commons from State Street
(Source: Gatech, 2010)

Georgia Tech University comprises a series of open spaces replacing existing parking lots, linked both physically and hydrologically as a continuous park extending through the north side of the campus. Since a sustainability goal for the project was to reduce storm water runoff to 1928 conditions, the designers worked to maximize infiltration, with hydrology and stormwater management in mind. A cistern system reuses rainwater and HVAC system condensation for site irrigation (Sorving, 2010). Eco-commons depends on a concept of high performance landscape where man-made and natural systems work together. First major goal is to reduce the stormwater footprint of the campus. This will be achieved with joining the capacity of landscape with smart infrastructure. Eco-commons is designed to prevent stormwater runoff and reduce contaminant discharge of first flush stormwater runoff. Also, improve underground water storage to mimic natural groundwater systems. In the Eco-commons phase-one (Figure 4.47); this concept is developed with natural woodland areas, man-made storage and irrigation systems to intercept, infiltrate, harvest and distribute stormwater condensate from buildings.

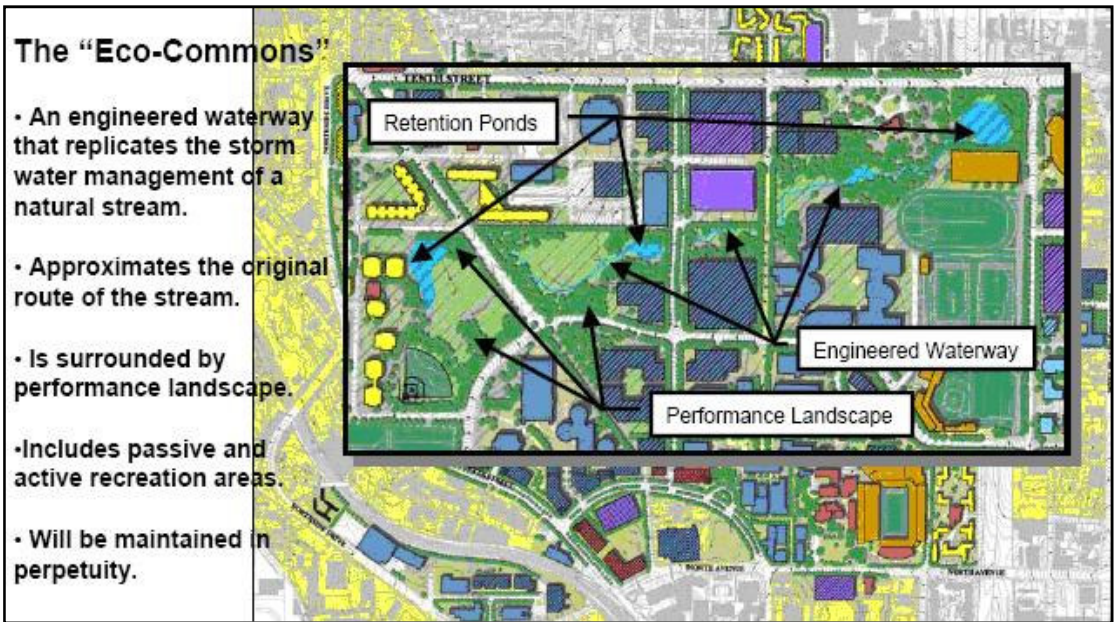


Figure 4.46. Georgia Tech Eco-Commons Project
(Source: Gatech, 2010)



Figure 4.47. Eco-Commons Phase I
(Source: Gatech, 2010)

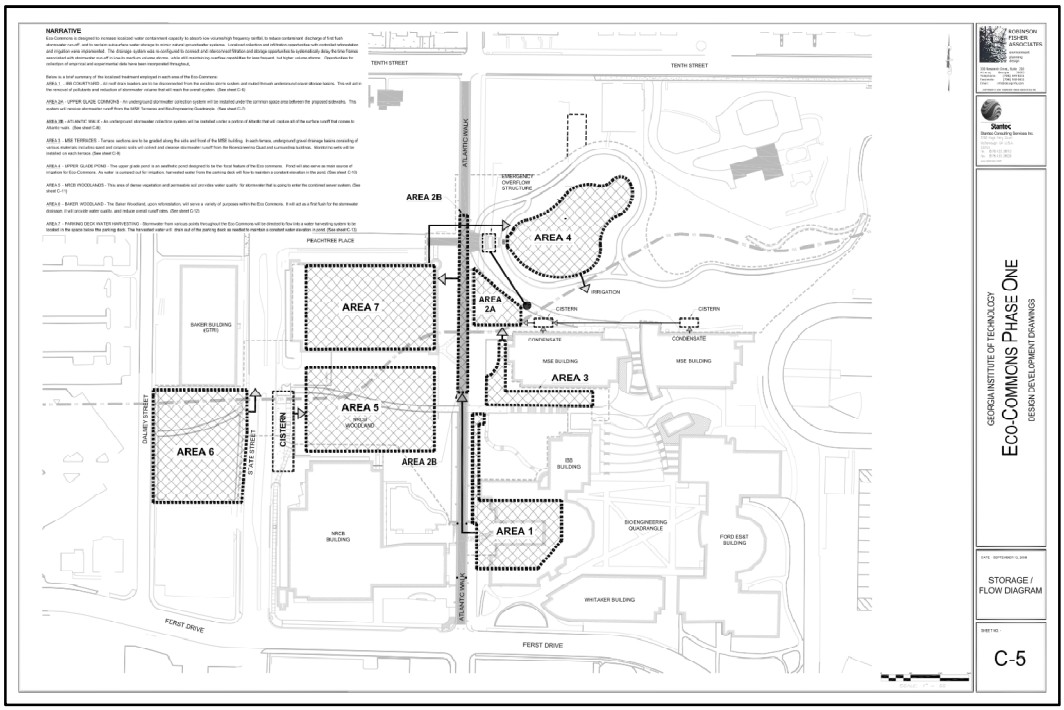


Figure 4.48. Eco-Commons Phase I Storage-Flow Plan
(Source: Gatech, 2010)

Campus Stormwater Management Plan aims to reduce the stormwater footprint of the campus and manage stormwater on campus. In storage-Flow plan of a Eco-Common Phase I shows stormwater storage areas both on aboveground and underground. There are seven areas in plan. Area one, two A, two B, three and seven has underground capturing and filtering function. Area four is an upper grade pond that serve as main source of irrigation for eco-commons. Area five and six are vegetated and forested permeable areas serve as pollutant removal of stormwater runoff. System capture surface runoff and roof drains and aims to remove pollutants and reduce stormwater value and provide water for irrigation.

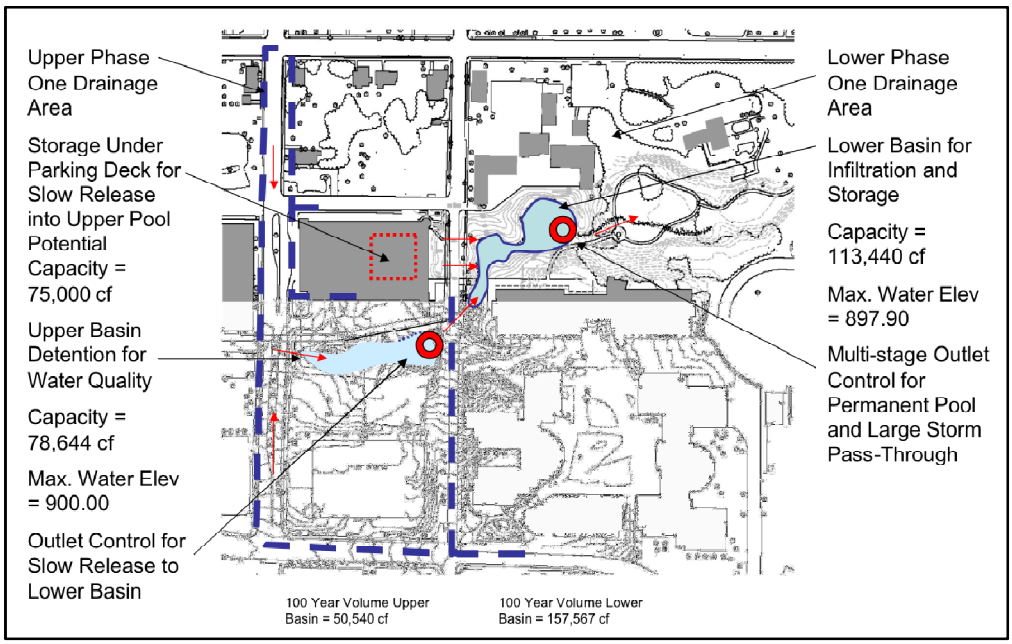


Figure 4.49. Eco-commons Detail
(Source: Gatech, 2010)

4.5. University of Arizona

University of Arizona Campus is located in a medium density neighborhood within one mile of downtown Tucson. The areas around campus were developed in the early to mid twentieth century. The project site is contained within the watersheds of

Rillito and Santa Cruz Rivers and more than half of the campus is covered with impervious surfaces, such as roads, sidewalks, buildings and parking lots.

University has prepared a Surface Water Master Implementation Plan to show the hydrological conditions of campus and update the floodplain boundaries of current condition because comprehensive campus plan include new buildings to be constructed and there will be environmental changes. Therefore, new design guidelines have been developed. The intent of the guidelines is to help reduce runoff throughout campus, conserve water and support sustainable landscape. University has developed a vision of recognizing the long-term value of water by conserving, harvesting, capturing and reusing it and providing models for the community with creative and innovative solutions to keep surface water on campus. Besides, they aim to integrate engineering and natural techniques. Therefore, problematic areas were specified with a site tour. It was seen that the existing conditions can be adopted to new techniques (Arizona, 2011).



Figure 4.50. Rainwater Drainage from Downspouts
(Source: Arizona, 2011)



Figure 4.51. Curb-cuts for Surface Runoff Drainage
(Source: Arizona, 2011)

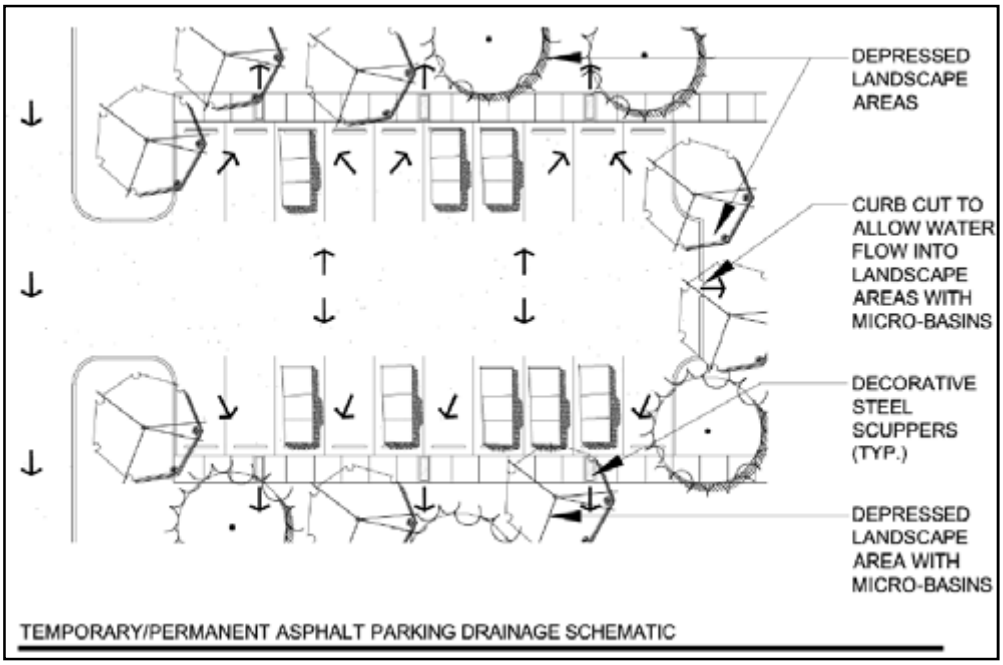


Figure 4.52. Parking Lot Surface Drainage Through Vegetated Area
(Source: Arizona, 2011)



Figure 4.53. Tree Well on Sidewalk
(Source: Arizona, 2011)

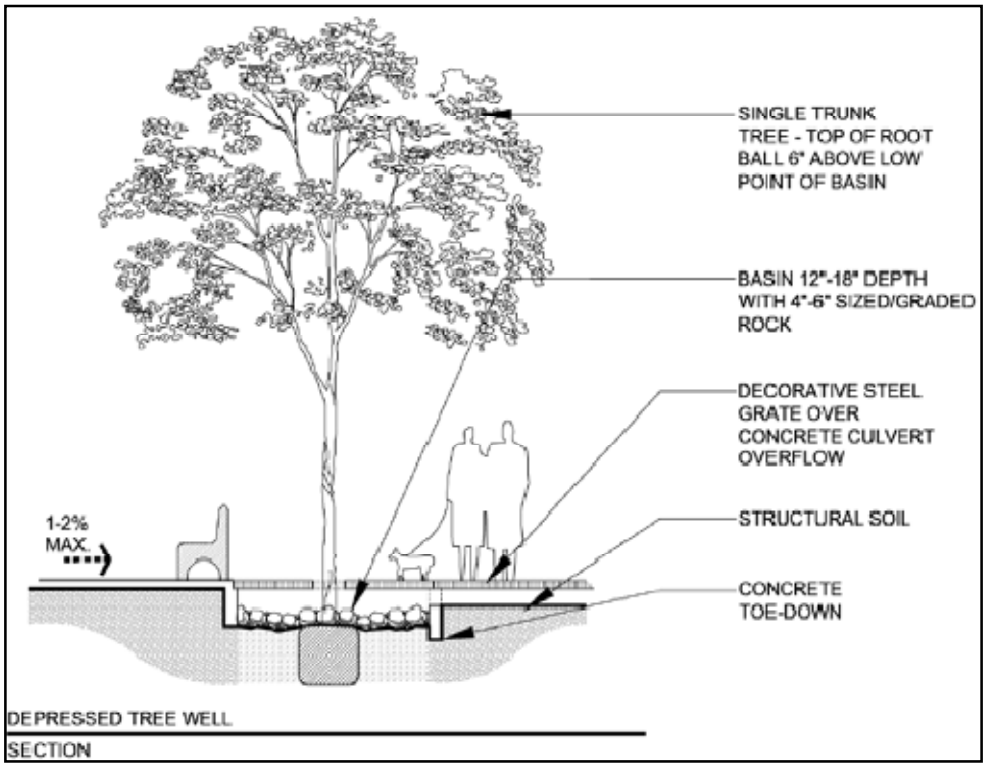


Figure 4.54. Tree Well Section
(Source: Arizona, 2011)

4.6. King Abdullah University of Science and Technology (KAUST)

King Abdullah University of Science and Technology campus and community site is located on the Red Sea adjacent to the fishing village of Thuwal and 80 kilometers north of Jeddah. The total area comprises more than 36 million square meters which including the University Campus, Harbor District commercial center, three distinct residential neighborhoods and a unique coral-reef ecosystem off shore (Kaust, 2011).



Figure 4.55. KAUST
(Source: Iie, 2011)

The Campus, which is constructed in 2009, is Saudia Arabia's first Leed Certified Project, earning Platinum Certification which is the highest rating in the United States' Green Building Rating System. Campus meets all the sustainability measures for energy, water, site, transportation and building.



Figure 4.56. Academic Buildings of KAUST
(Source: Carboun, 2011)

Water conservation is critical in Saudia Arabia and the average rainfall on the site of KAUST is low, annually 54 mm, and mostly rainy days are in winter. Most of the potable water is provided from desalinated sea water but this desalination cause high energy consumption so some strategies were developed by design team of Campus to reduce potable water consumption and comprehensive irrigation plan was developed (Figure 4.56). According to the plan all black and grey water will be treated and used for campus irrigation. Besides, native vegetation and adaptive plants were planted on site which are requiring less irrigation and efficient drip irrigation system has been using. On the other hand, campus stormwater management plan reduces impervious surfaces, increase groundwater infiltration and capture and treat all annually rainfall runoff on campus. Also, low flow fixtures have been used in campus buildings providing to reduce water consumption. Therefore, water reclaimed from condensate and annually rainfall runoff, gray and blackwater systems, low-flow fixtures have reduced demand by 40 percent (Europa, 2010).

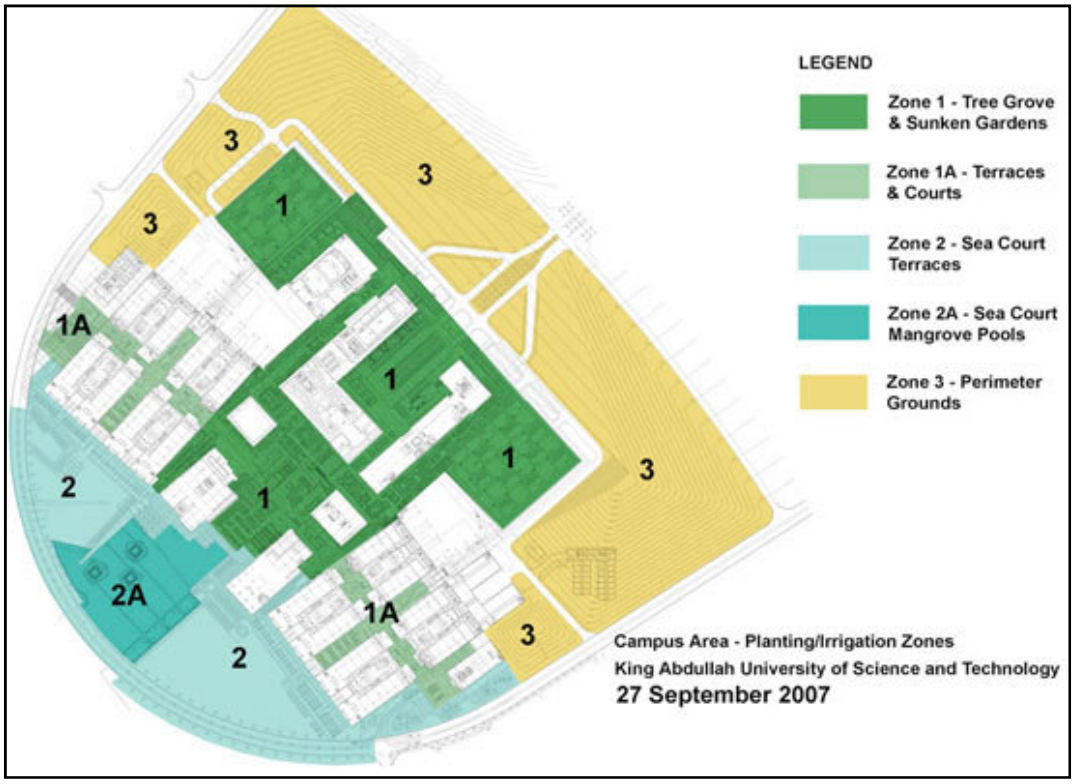


Figure 4.57. Comprehensive Irrigation Plan of KAUST
(Source: KAUST, 2011)

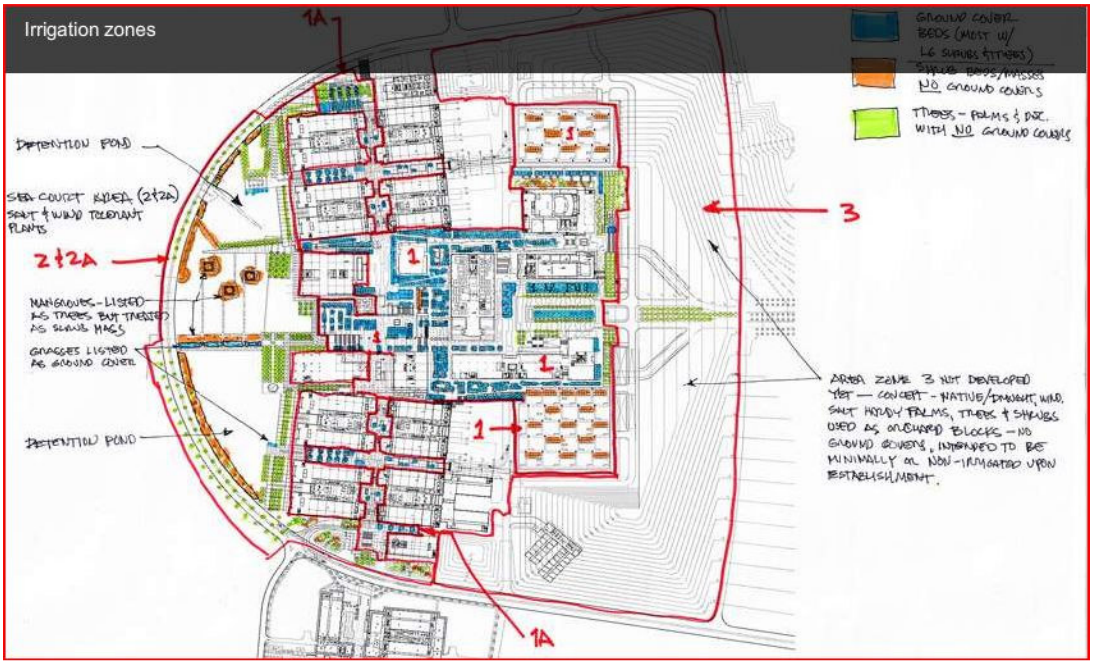


Figure 4.58. Irrigation Zones of KAUST
(Source: Kaust, 2011)

4.7. Demonstration Projects of University Campuses

While many campuses integrated green infrastructure in campus master plans some have demonstration projects. Here some of the demonstration projects are introduced. These are Massachusetts Institute of Technology "The Stata Center Rainwater System, Villanova University (Pennsylvania) "Stormwater Research and Demonstration Park", University of Arizona "Sonoran Research Laboratory".

4.7.1. Massachusetts Institute of Technology "The Stata Center Rainwater System"

The Stata Center at Massachusetts Institute of Technology is designed according to the green standards based on the US Leadership in Energy and Environmental Design Program (LEED). Efficient uses of water and stormwater management are the part of the green standards.Water efficiency at Stata was provided with the efficient site design for stormwater management. Pervious paving and green roofs are provided as stormwater management techniques. As a result; the rate of stormwater runoff from the site is reduced by % 50 and the amount of solid by % 80. Also, use of potable water for irrigation was limited and indigenous plants are used. Stormwater management system in the building includes the storage, treatment and reuse of the stormwater. In the system the runoff Stata Center site and the adjacent buildings roof enter the outwash basin either through high level or low level drains. High level drains discharge into the upper portion of the basin, entering the created wetlands region. When the upper part is full, wetland area overflows into the lower portion of the system. The lower portion of the basin is an underground rainwater storage chamber. At the Massachusetts Institute of Technology campus (Cambridge, MA) consists of a rock-filled swale, which is essentially dry, except in the event of very large storms. Roof drains convey water directly to the underground detention/ storage chamber, while a network of pipes and conduits convey water directly underground. Solar powered recirculation pumps recycle water back up to the surface for reuse in water cisterns and toilets within the buildings, and an impervious layer beneath the subterranean detention chamber aids in storage of water. The design addresses a variety of stormwater function such as detention,

filtration, and rainwater harvesting (MIT Stata Center-A Benchmark for Green Standards, 2008).

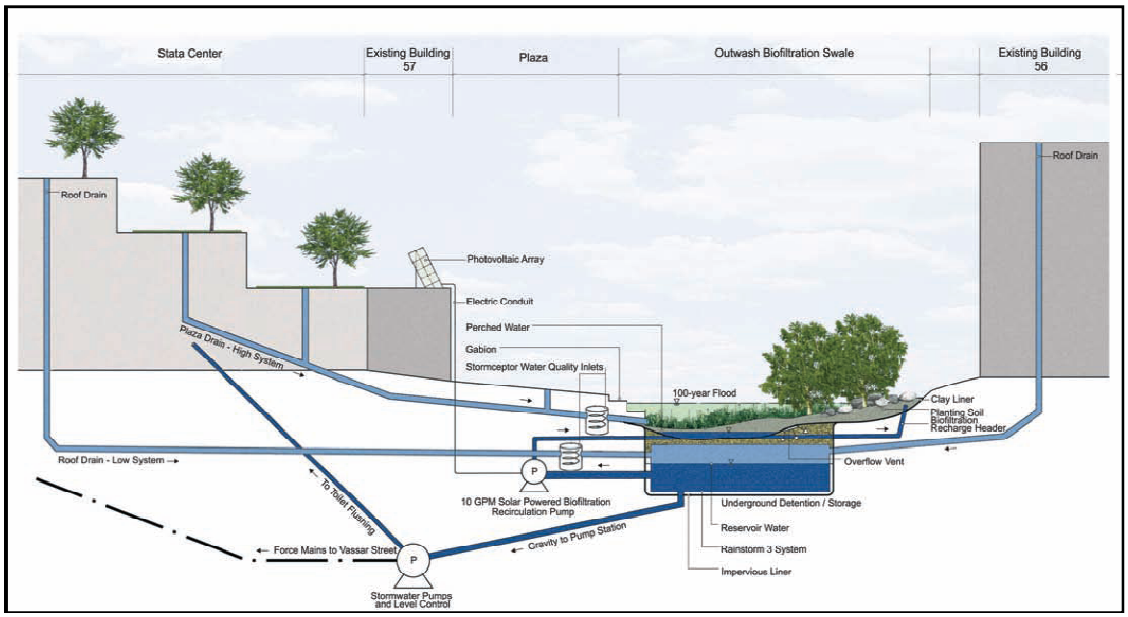


Figure 4.59. MIT's Stata Center Rainwater System
(Source: MIT, 2010)



Figure 4.60. Stata Center
(Source: Artfulrainwaterdesign, 2010)



Figure 4.61. Stata Center Wetland
(Source: Artfulrainwaterdesign, 2010)

4.7.2. Villanova University (Pennsylvania) "Stormwater Research and Demonstration Park"

In 2002, The Pennsylvania Department of Environmental Protection (PADEP) and Villanova University's Department of Civil and Environmental Engineering formed the Villanova Urban Stormwater Partnership (VUSP). Current Best Management Practice study sites include a pervious concrete/porous asphalt comparison, a bio-infiltration traffic island (constructed in 2001), an infiltration trench, a storm water wetland (constructed in 1999) and a green roof (constructed in 2006). The green roof design was a retrofit of a small portion of Villanova's Center for Engineering Education Research (CEER) roof on a second storey terrace. The BMP Park plays an important role in advancing stormwater management practices (Villanova-2).

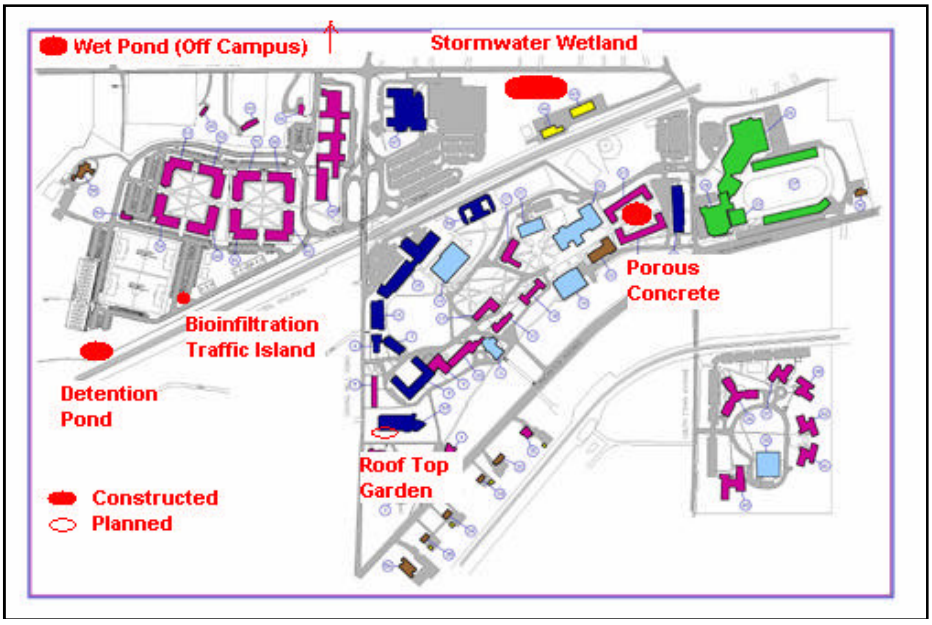


Figure 4.62. Villanova University Stormwater Research & Demonstration Park (Source: Villanova-1, 2010)



Figure 4.63. Stormwater Wetland
(Source: Villanova-2, 2010)



Figure 4.64. Bio-infiltration Traffic Island
(Source: Villanova-2, 2010)



Figure 4.65. Porous Concrete Demonstration Site
(Source: Villanova-2, 2010)



Figure 4.66. Infiltration Trench
(Source: Villanova-2, 2010)

4.7.3. University of Arizona“ Sonoran Research Laboratory”

Sonoran Research Laboratory at the university of Arizona is a high performance landscape garden as a model for sustainable design in the arid region. In front of the Landscape Architecture Building has been turned into a garden from a parking lot (Figure 4.69). The aim of the Project is to provide sustainable water management practices for building greywater and stormwater runoff. An extensive water harvesting system collects roof runoff, HVAC condensation and building waste from sinks and drinking fountains in a 11.600 gallon storage tank. Later, these tanks provide water for high-efficiency drip irrigation system. The system harvest approximatelly 230.000 gallon water annually. On the other hand, surface water runoff on rainy days is directed to flow into a desert pond (Figure 4.69) and then a bioswale (Asla-2, 2010).



Figure 4.67. Sonoran Research Laboratory (Source: Asla-2, 2010)



Figure 4.68. Sonoran Research Laboratory (Source: Asla-2, 2010)



Figure 4.69. Sonoran Research Laboratory Pond (Source: Asla-2, 2010)

4.8. Sustainable Campus Development in Turkey

In Turkey, stormwater management issue has been developing recently because of global warming and as Turkey is analyzed for its climatic conditions, it is seen that the rainfall quantity changes year by year and rainfall quantities are generally less except for two regions (Figure 4.70). Therefore, Turkey has mostly semi-arid regions.

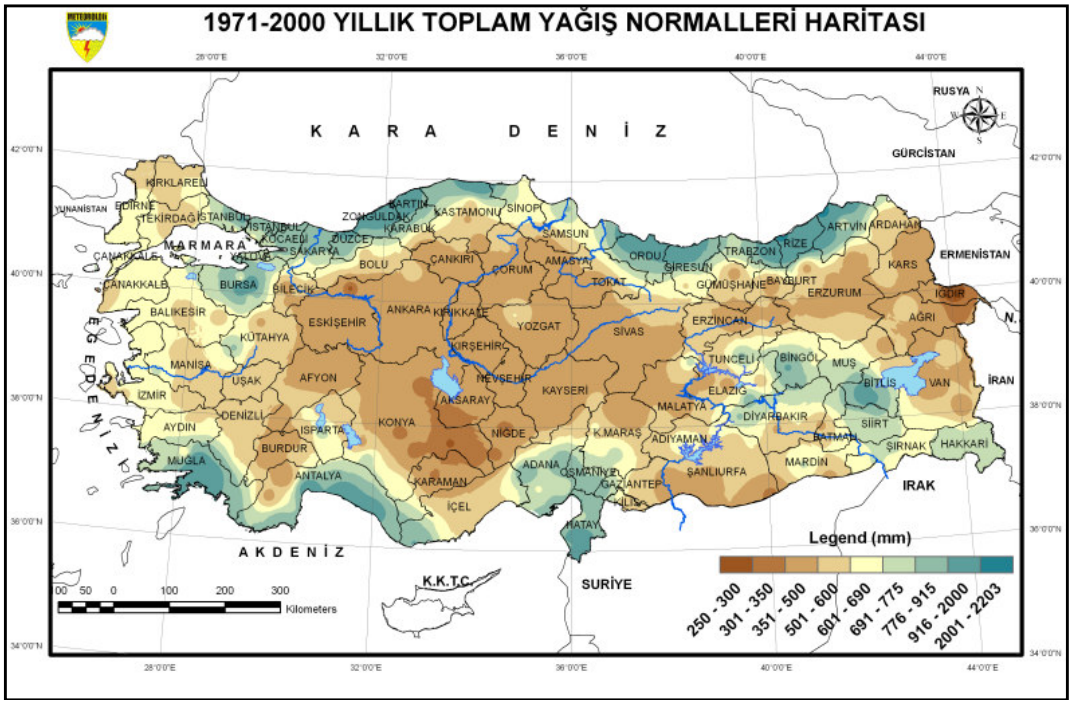


Figure 4.70. Rainfall Quantity between the years 1971 to 2000 in Turkey (Source: Dmi, 2011)

Sustainability concept has not been widely adopted to university campus developments yet. The existing developments have not considered the environmental sustainability assets. When analyzed the university's approach to sustainability assets mostly, universities in Istanbul have studies on sustainability.

The universities of Middle East Technical University (METU), 19 Mayıs, Muğla and Sabancı are aimed to be "Green Campus" so these universities have developed some strategies for the project of "Climate Sensitive Campuses". According to this project, METU aims to use electric cars and construct waste refinery on campus; 19 Mayıs University aims to construct wind plant, Muğla University aims to construct a power plant and lastly Sabancı University aims to develop an Eco-Campus Project. The aim of the project is to solve environmental problems and increase consciousness on campus so recycling, resource degradation, reuse, organic products and forestration of campus are the goals of the study. In addition to others, Sabancı University intends to construct green building in world standards. Also, Sabancı University organized seminars and panels about sustainability and environmental issues. Besides, recycling, holding the rainwater from rooftops and get benefit from sun and wind energy are the strategies for the other universities to be applied for the Climate Sensitive Campuses project (yesilbinadergisi, 2011 and marbleport, 2011). Except for the projects, Sabancı

University has an environmental approach for water management and has a pond on their campus. They have downspout system in faculty buildings. The collected rainwater from rooftops is drained to pond and reused afterwards for their campus irrigation (Sabanciuniv, 2011).



Figure 4.71. Sabancı University Pond Area
(Source: Sabanciuniv, 2011)



Figure 4.72. Sabancı University Pond Area
(Source: Sabanciuniv, 2011)

On the other hand, Istanbul University has investigation station about catchment area hydrology and arboretum and lastly, Boğaziçi University Kilyos Campus has conducted wind measurements for Green Campus Project. However, recently some of the new developing campuses started to adopt sustainability concept to their design. They aim to become a green campus but there hasn't been any applications yet. Firstly, the strategies are defined by universities. They aim to develop sustainable strategies at both building scale and campus scale. Generally, the strategies are developing in the categories of site, energy, water, landscape, infrastructure, transportation and building design. For example, Özyeğin University Campus in İstanbul is to be developed

according to sustainability criterias and aims to get LEED Certificate. Thus, design approach of the campus is to be compatible with nature (Figure 4.73).



Figure 4.73. Future Site Plan of Özyeğin University
(Source: Ozyegin, 2011)

Design Principles for stormwater management are; to design sustainable stormwater systems with an aim of capturing the stormwater to reuse, decrease the hardscape surfaces and increase the pervious surfaces, construct the buildings with greenroof and use greywater systems to reuse after treatment (Ozyegin, 2011).



Figure 4.74. Future Academic Buildings
(Source: Ozyegin, 2011)



Figure 4.75. View from Plaza
(Source: Ozyegin, 2011)

4.9. Summary and Evaluation

As a result, protection of water resources becomes an important issue for universities in the world. Most of the universities adopt sustainability concept to their campus design. Sustainable Water Management strategies are expressed in university campus examples. Most of them has water management plan or landscape master plan to express their approaches. These plans also include their analysis, design guidelines, application techniques and practices. Generally, they create interaction between landscape design and stormwater management plan. Application scale changes according to universities' view for water management. Some of them applied their guidelines to entire campus area, but some has only demonstration projects or some of them only develop strategies and do not have any applications. On the other hand, sustainability concept has not been widely adopted to university campus developments yet in Turkey, recently new developments have started and design standards have started to change to be green campus so these approaches are initial steps for Turkey.

CHAPTER 5

THE CASE OF IZMIR INSTITUTE OF TECHNOLOGY CAMPUS

This Chapter explains the case study part of the thesis. The Case study area is İzmir Institute of Technology (IYTE) Campus. Firstly, IYTE Campus is analyzed according to the topography and slope, elevation, geology and soil, landscape, climate, drainage and water resources. Then, Campus existing Master Plan along with campus development history and Infrastructure Analysis are presented. Later, existing problems and opportunities for existing and future conditions are defined for Campus with an evaluation of constraints, and lastly recommendations and the Best Management Practices are identified into categories of structural and non-structural BMPs for sustainable stormwater management on IYTE Campus.

5.1. Site Analysis of IYTE Campus

Izmir Institute of Technology (IYTE) campus is located approximately 50 km from the city center of Izmir nearby the small rural village of Gulbahce (Urla) (Figure 5.1). Campus area is restricted with Izmir-Çeşme Highway to the south, Barbaros Village and Kocadağ Hill on the west, Urla to the east and Gülbahçe Village on the north. The Campus Area is on 2. Degree Natural Preservation Site and has been developed on an undisturbed site since 1994 nearby a rural area with some agricultural production by village inhabitants. The entire campus covers 3500 ha but the present campus built up area is only 154 ha (Figure 5.2). There are still ongoing building constructions. Following analysis are conducted for the built-up area of IYTE Campus.



Figure 5.1. Location of the IYTE Campus
(Source: Buyutec, 2011)



Figure 5.2. Aerial View of IYTE Campus Area Boundaries
(Source: Google Earth, 2005)



Figure 5.3. Aerial View of IYTE Campus Built Up Area
(Source: Google Earth, 2005)

5.1.1. Topography and Slope

The site has a rising and falling topography. The slope ratio changes between the % 0-30 (Figure 5.4) and elevation of the campus area changes between 22m to 110m. There are two major hills at campus. One of them is close to cafeteria building and there are two water tanks on it. One of them is potable water tank used for campus and the other one is treated water pool for campus plant irrigation. The other hill is close to rectorship building which has been excavated for sport and computer engineering buildings.



Figure 5.4. Iyte Campus Slope Analysis

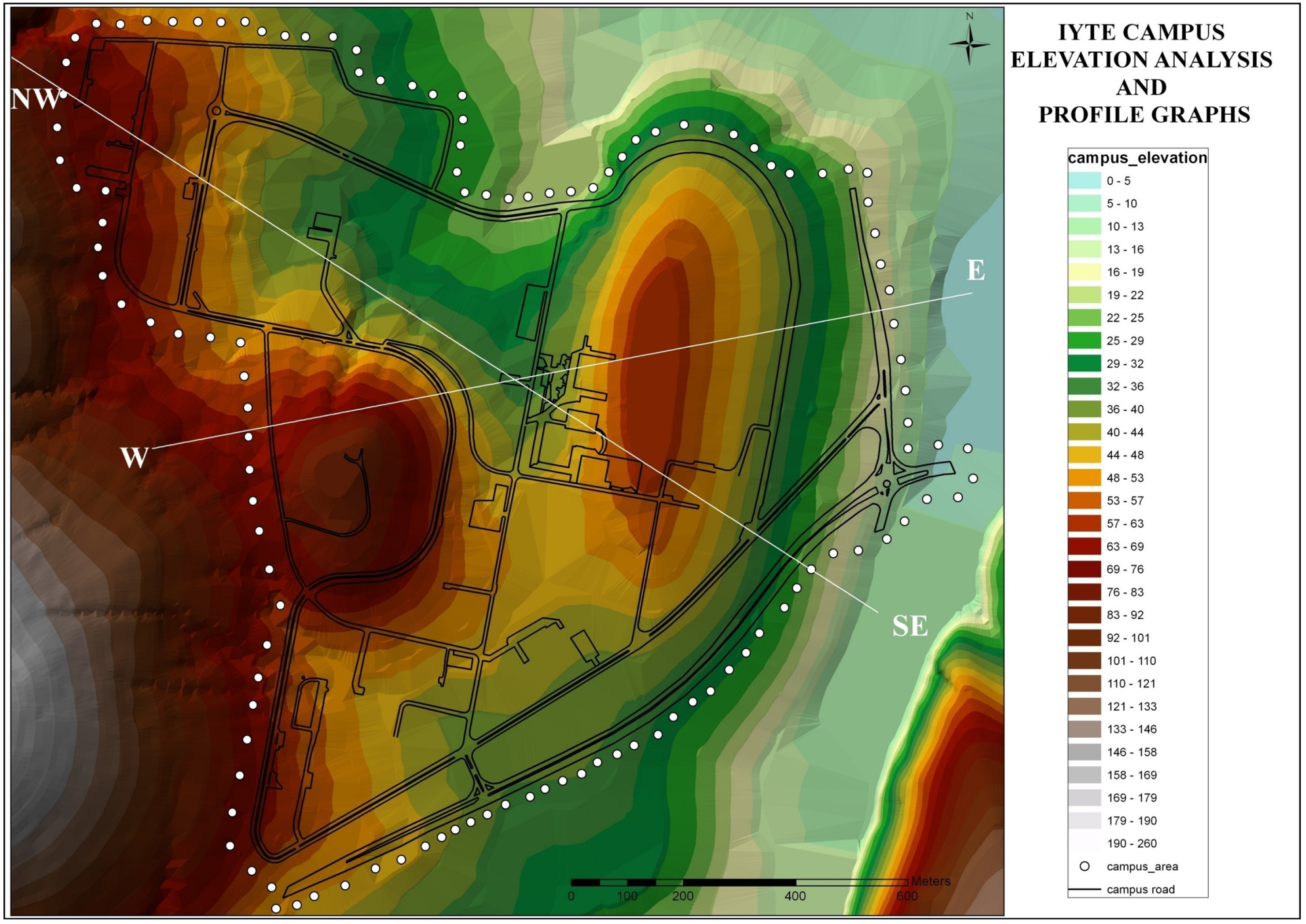


Figure 5.5. Iyte Campus Elevation Analysis

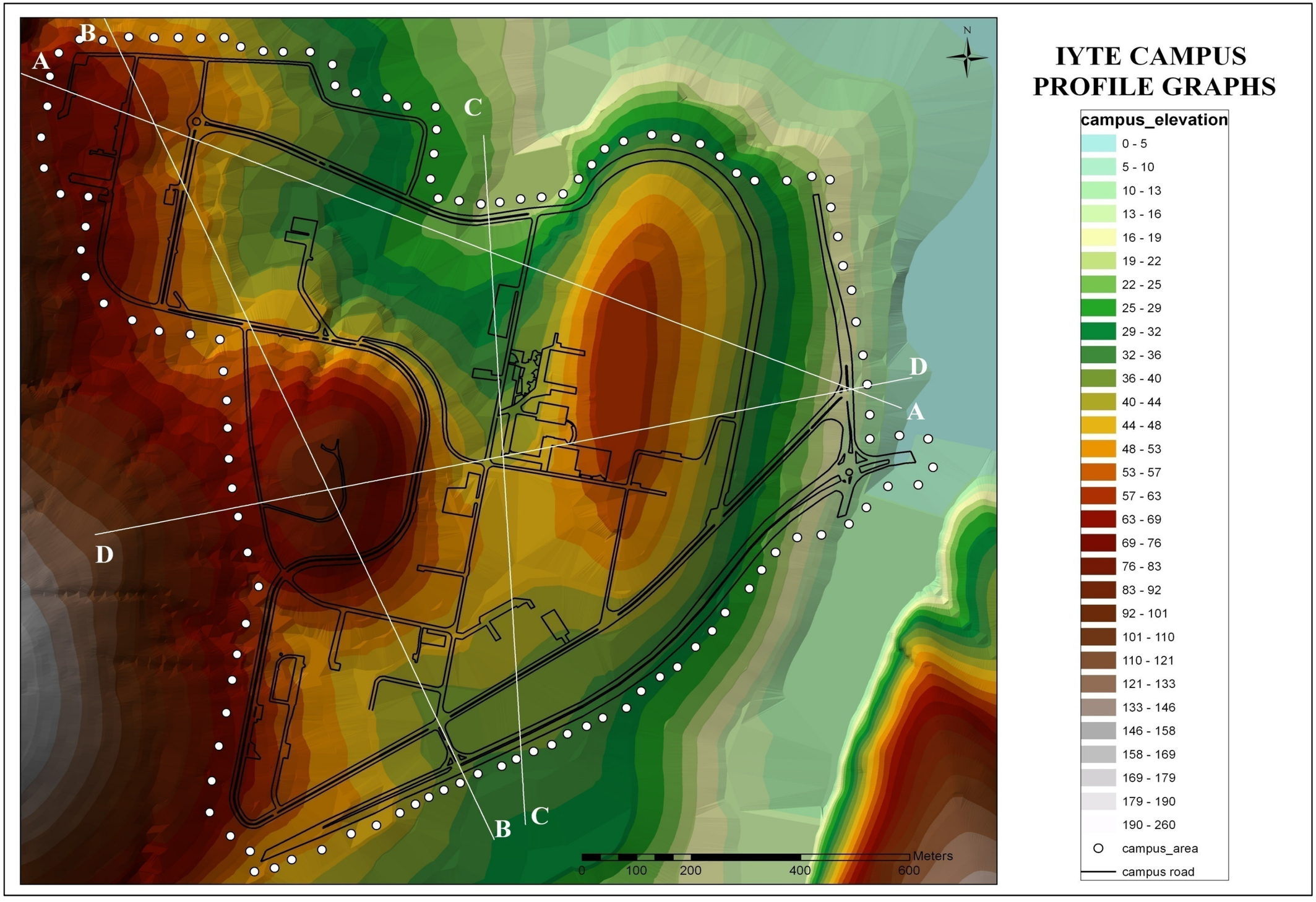


Figure 5.6. IYTE Campus Profile Locations

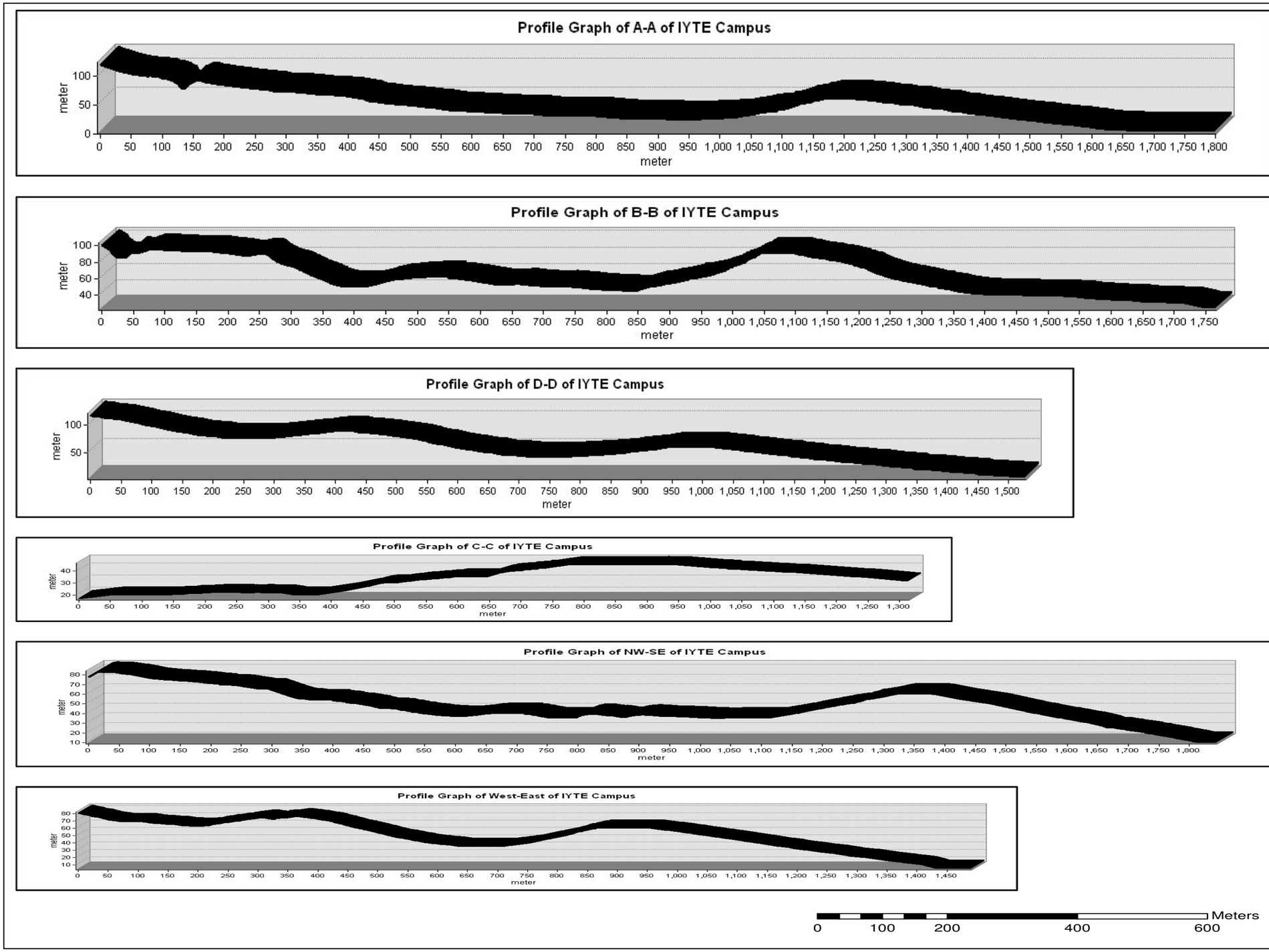


Figure 5.7. IYTE Campus Profile Graphs

5.1.2. Geology

Different rock formations are seen on campus and its surrounding. Cretacous limestone is the basement of study area. Miocene rock consists of andesites, andesite breccia of lava flows, agglomerates, volcano-sediments and recent sediments (Figure 5.9). Recent sediments induce to be appeared as alluvions, colluviums, slope debris, swamp and coast sediment. Research is conducted on Sinekli River and near faculty housing. The aim of geological investigations on campus is to identify the lithological features and their water storage capacities on rainy days to recharge groundwater. In project area, surface water is proposed for underground storage so five geophysical measurements are conducted (Figure 5.8).



Figure 5.8. Geophysical Measurement Points
(Source: Baba et al., 2010, p.11)

According to the analysis, the high points of topography on the west of faculty housing has andesites with cracks but in project area, there are agglomerate and tufas and some volcanic units that turned to clay. Andesites are in a position of aquafier with cracks and tufas are impervious (Baba et al., 2010).

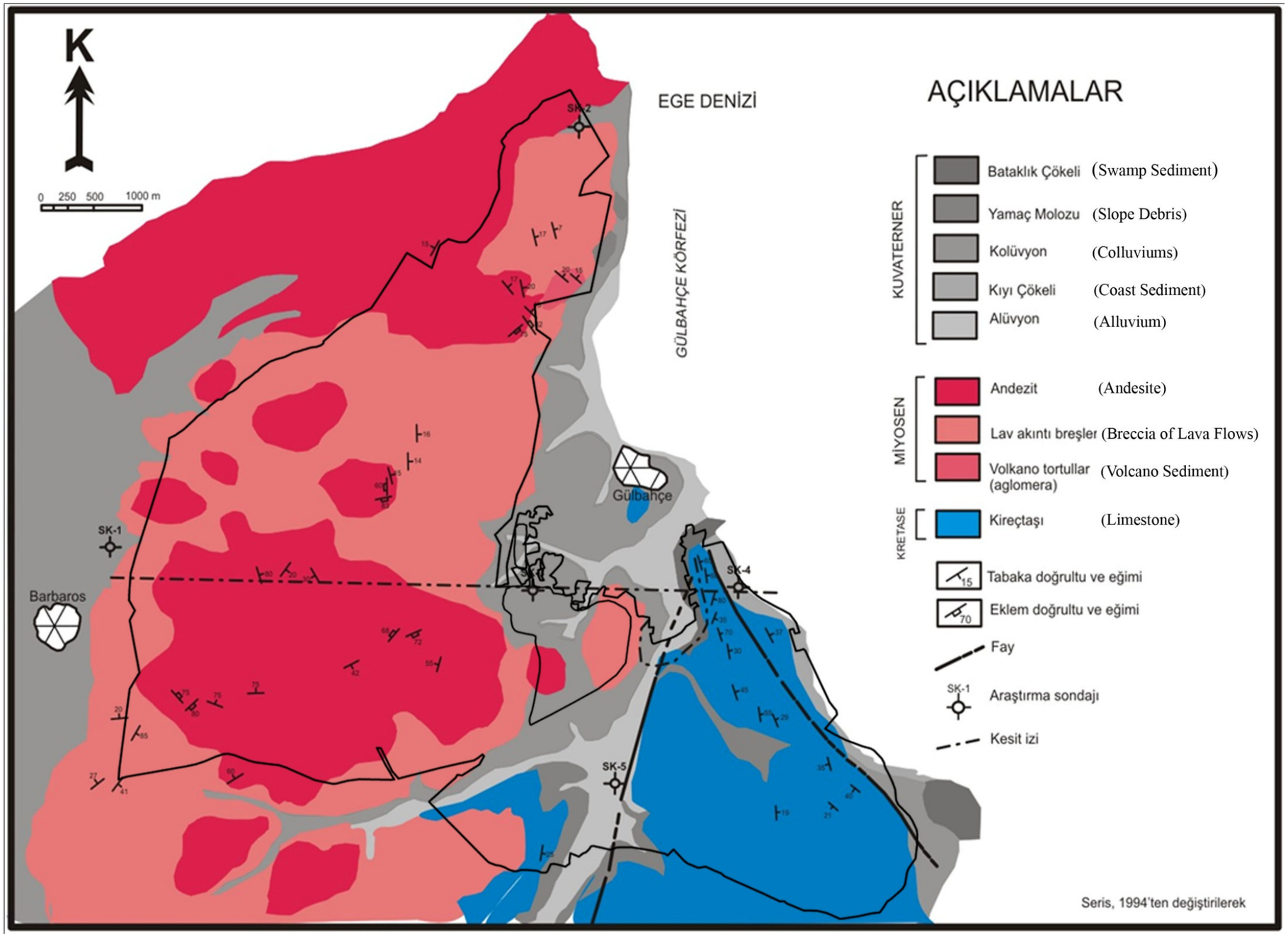


Figure 5.9. Iyte Campus Geological Analysis (Source: Baba et al., 2010, p.3)

On the otherhand, campus is located on active fault system. Therefore, it can be seen different magnitute of facult on this zone (Figure 5.9). These faults had cause an earthquake in 2005. Faculty buildings are damaged, especially Faculty of Architecture was effected mostly. Generally, type of soil is clay with low infiltration rate therefore underground water resources are limited. Also, low infiltration conduce to occur ponds in some parts of the campus.

5.1.3. Vegetative Cover

Site is covered dominantly with native plants. The campus landscape is typical of the Aegean region, which consist on maquis (maki), erica (funda), olive and pistacia lentiscus (sakız) trees. Native plants include; lavandula stoechas (Karabaş otu), Spartium (Katırtırnağı), Cistus Incadens (Laden), Juniperus Communis (Ardıç), Tamarix Tetranda (Ilgın) and Thuja Occileritaris (Mazı) which are classified as shrub. Besides, Anemone Coronaria (Anemon), İris Persica (Nevruz Çiçeği), Muscari Armeniacum (Sümbül) and Anthemis (Papatya) which are classified as herbaceous (Ekşi, 2011).

Existing campus area has mostly natural landscape areas which are hill points and the areas of non-constructed. Besides, some part of them are turned into woodland and cultivated landscaped areas (Figure 5.13). Cultivated landscape areas are mostly disturbed and constructed areas that include the surroundings of the buildings, the plazas, sport areas. Generally, pine and olive trees are added. Also, there are some grass areas as well but not expansive since maintenance and irrigation is not easy on this site. Seasonal changes cause colour changes in the vegetative landscape (Figure 5.11 and 5.12). There is a greenhouse close to the Faculty of Science where Campus trees and plants are grown locally. 77.574 plants have been grown since 2008 and 42.168 plants have been added to campus landscape (Ekşi, 2010).



Figure 5.10. Vegetative Colour in Winter
(Source: Toksoy Personal Archive)



Figure 5.11. Vegetative Colour in Summer
(Source: Toksoy Personal Archive)



Spartium/Katırtırnağı



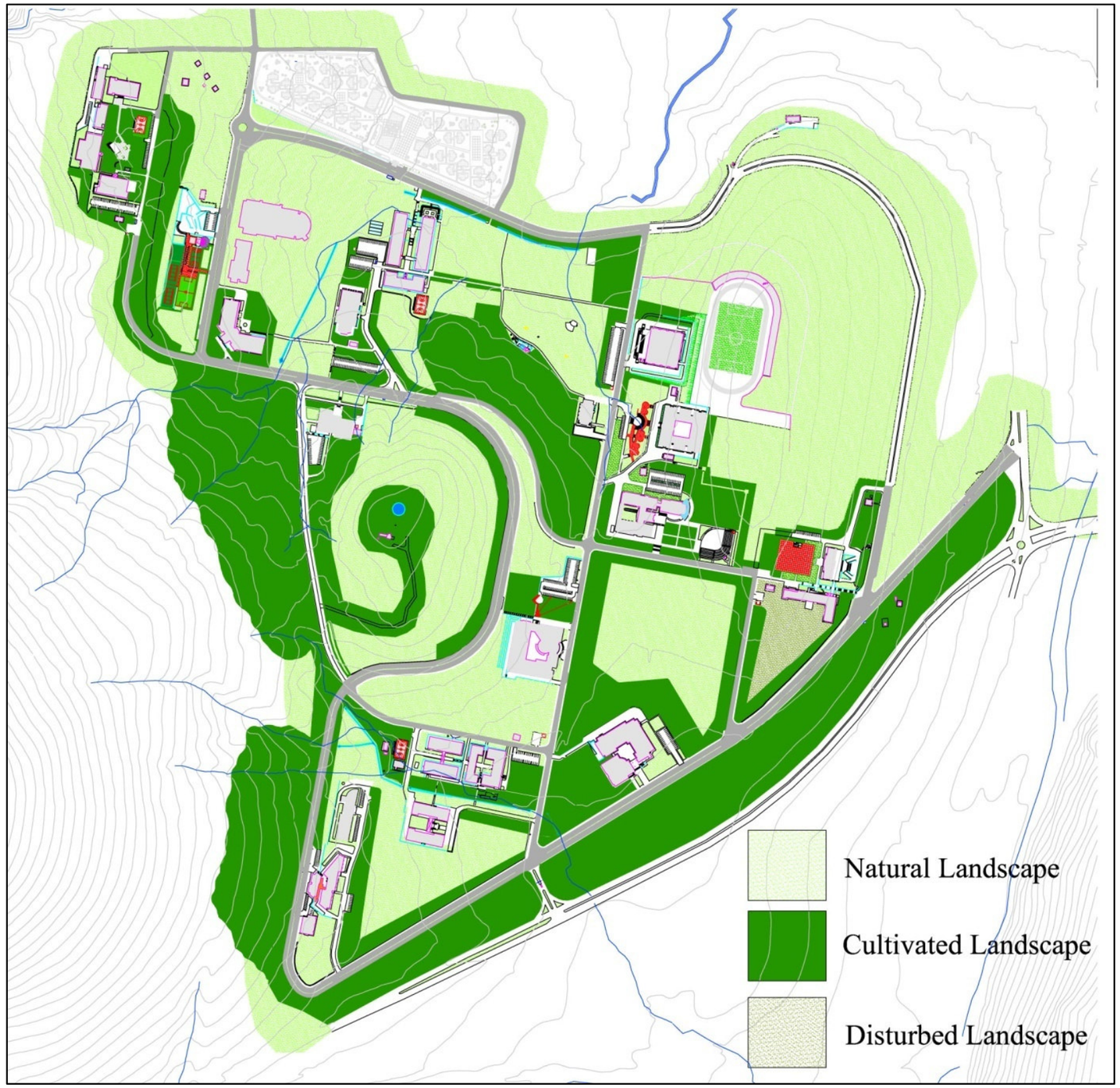
Juniperus Communis/Ardıç



Lavandula Stoechas/Karabaş Otu



Muscari/ Arap Sümbülü





Anemone Coronoria/Anemon



Cistus Incadens/Laden



Tamarix Tetrandra/Ilgın



Erica/Funda

Figure 5.12. Vegetative Cover of IYTE Campus

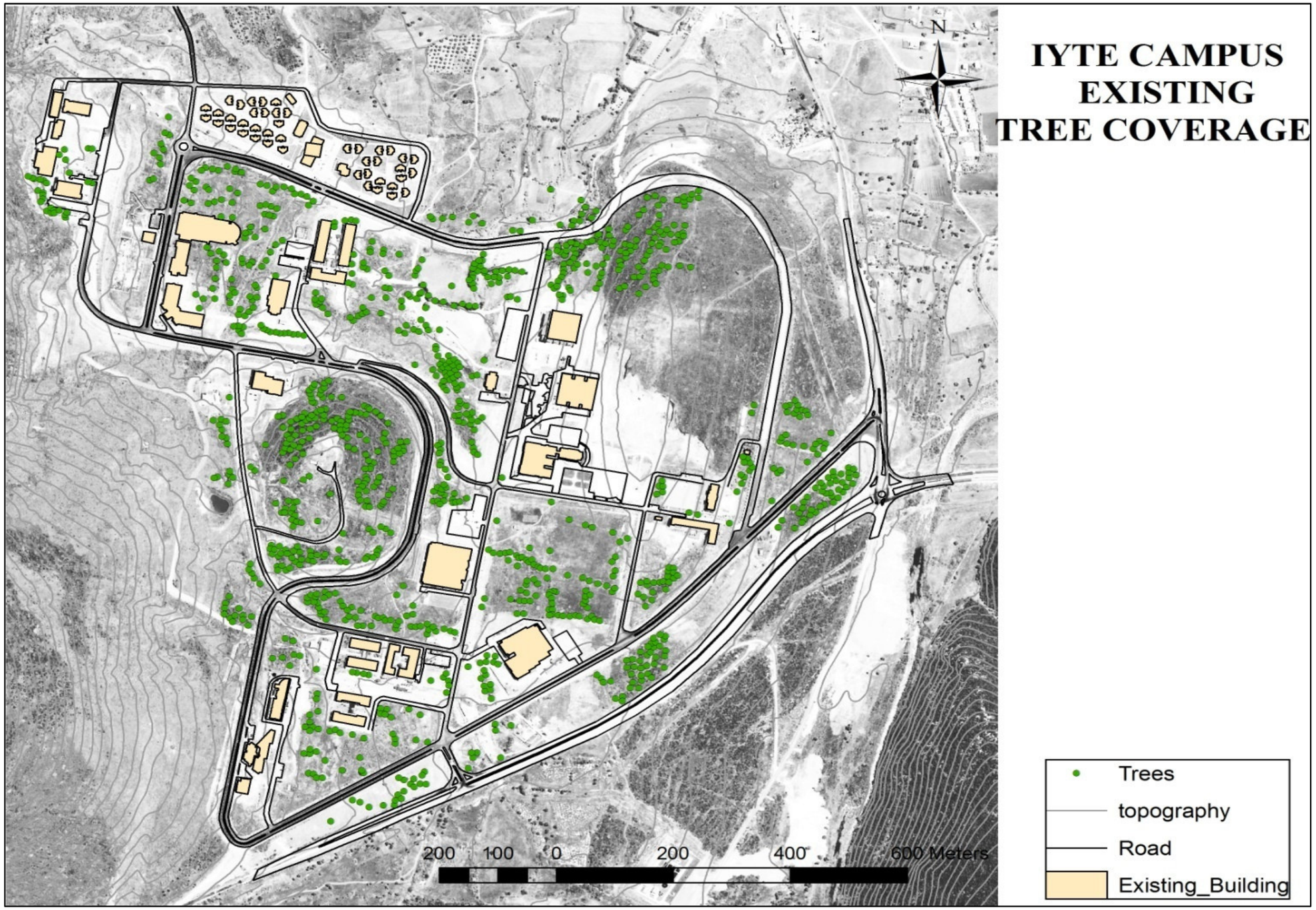


Figure 5.13. Existing Tree Coverage of IYTE Campus



Figure 5.14. Cultivated Landscape



Figure 5.15. Cultivated Landscape



Figure 5.16. Cultivated Landscape



Figure 5.17. Cultivated Landscape



Figure 5.18. Cultivated Landscape



Figure 5.19. Cultivated Landscape

5.1.4. Climate

The climate type of the IYTE Campus is mediterranean. Generally, summers are hot and dry sometimes rainy and winters are temperate and rainy. The average temperature of campus is 17 ^{0}C degree according to measurements done between the dates of 2008 October to 2010 June (Tayfur, 2007). Generally, the minimum temperature is 5 ^{0}C and the maximum is 32 ^{0}C in Campus (Figure 5.20).

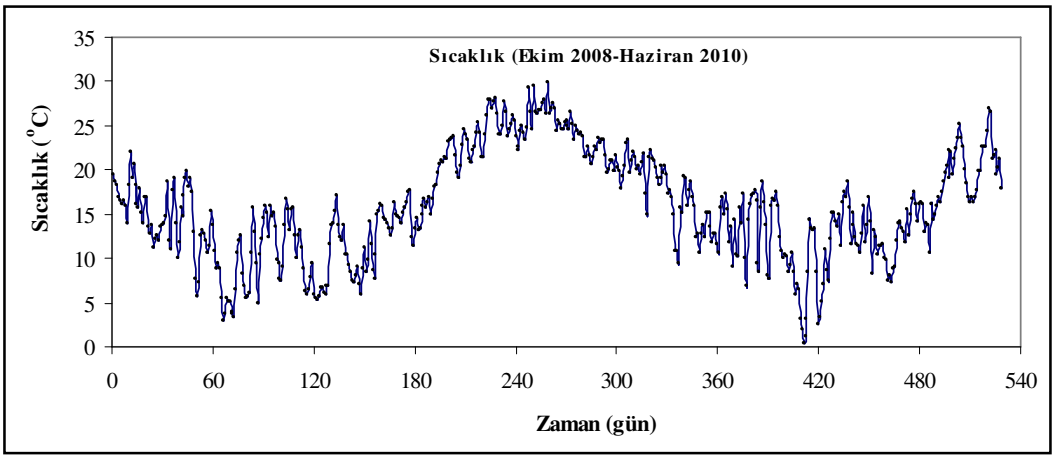


Figure 5.20. IYTE Campus Temperature Variation
(Source: Tayfur, 2010, p.10)

Also, Moisture and Wind Speed measurements were done in research project and results show that the prevailing wind direction is north in campus (Figure 5.22) and the average moisture is % 40 in summer and % 90 in winter (Figure 5.21).

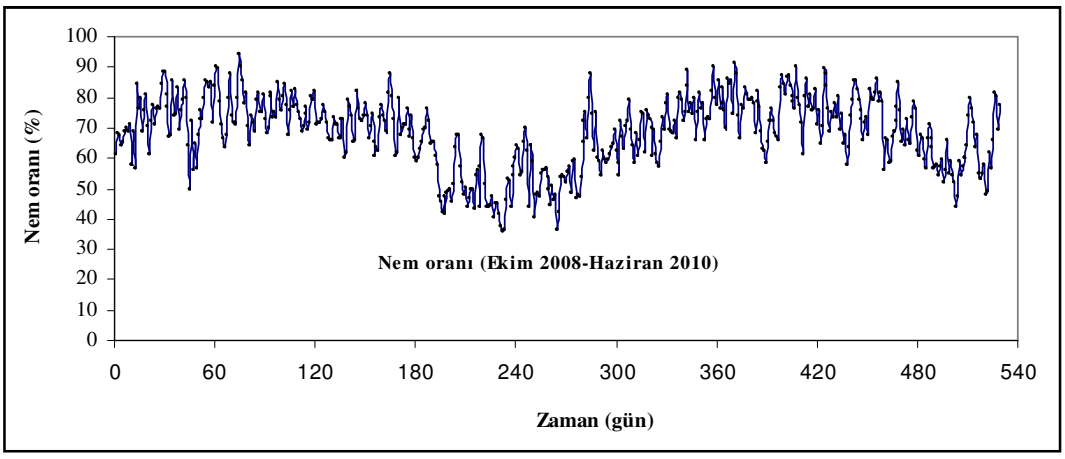


Figure 5.21. IYTE Campus Moisture Variation
(Source: Tayfur, 2010, p.10)

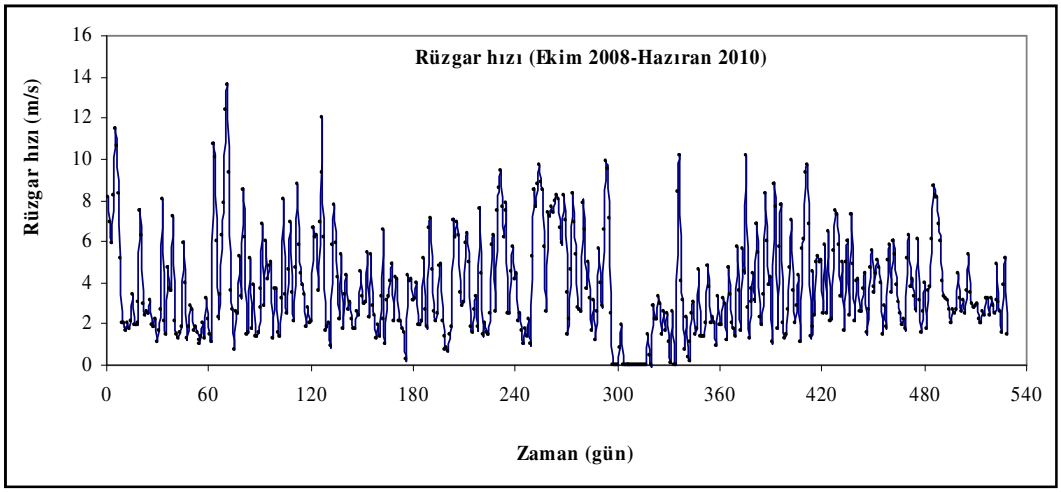


Figure 5.22. IYTE Campus Wind Speed Variation
(Source: Tayfur, 2010, p.11)

On the other hand, the average rainfall changes year by year. There are only 2008 and 2009 rainfall data for campus so rainfall quantity was changing according to these years.

5.1.5. Watershed Context and Water Resources

The campus streams and their watershed areas provide an underlying foundation for this study. In general, the campus has a watershed basin according to the surrounding rivers and their efficiency zones. After the boundary of watershed basin is setted, the ridge line is created according to the hill points in the basin and last, sub-basins are drawn with taking reference of drainage divide. These sub-basins are created according to the streams and water flow directions on campus (Figure 5.28). Campus built up area is generally, composed of two basins (north and south) based on topography and natural drainage ways (Figure 5.29). The north side of the runoff drain to north basin and south side of runoff drains to south basin.

There are natural stream beds, a waterfall and a natural pond as well as a manmade pond which is a recent addition on campus in 2010 (Figure 5.23 to 5.27). Also, there are manmade ponds on the other face of the Sinekli Mountain that is facing west the Barbaros Village. As the university has grown, some of the stream beds have been buried in concrete channels and one stream has been changed its course due to development. IYTE Campus area include many streams. These streams should be

considered with flood potential for built up area. According to DSI Report (1993) only Tatar, Şirin and Kavaklı streams should be rehabilitated because of flood risk, but other stream beds should be protected. The surface water opportunities are analyzed in north and south of campus in the study of Investigating Surface and Ground Water Potential of Izmir Institute of Technology Campus (Tayfur, 2010). In Tayfur's investigation, the study area is restricted with Tatar river in the south and Karapınar river in the north. This area includes most of the streams but excludes the Tatar, Karapınar and Kavaklı rivers, the other river basins are not proper for storage because of the topography. Besides, groundwater opportunities are analysed according to the measurements of two wells (Figure 5.34) and it has been expressed briefly in the water resources part of this chapter. On the other hand, according to the Baba's investigation, water can be supplied from andesites with drilling. There are geological faults in the area and thermal water springs. The thermal water temperature is 33 ^{0}C, so it is not enough to heat the faculty buildings.



Figure 5.23. Stream on Campus
(Source: Google Earth, 2005)



Figure 5.24. Waterfall on Campus



Figure 5.25. Waterfall on Campus



Figure 5.26. Natural Pond on Campus
(Source: Toksoy Personal Archive)



Figure 5.27. Manmade Pond on Campus

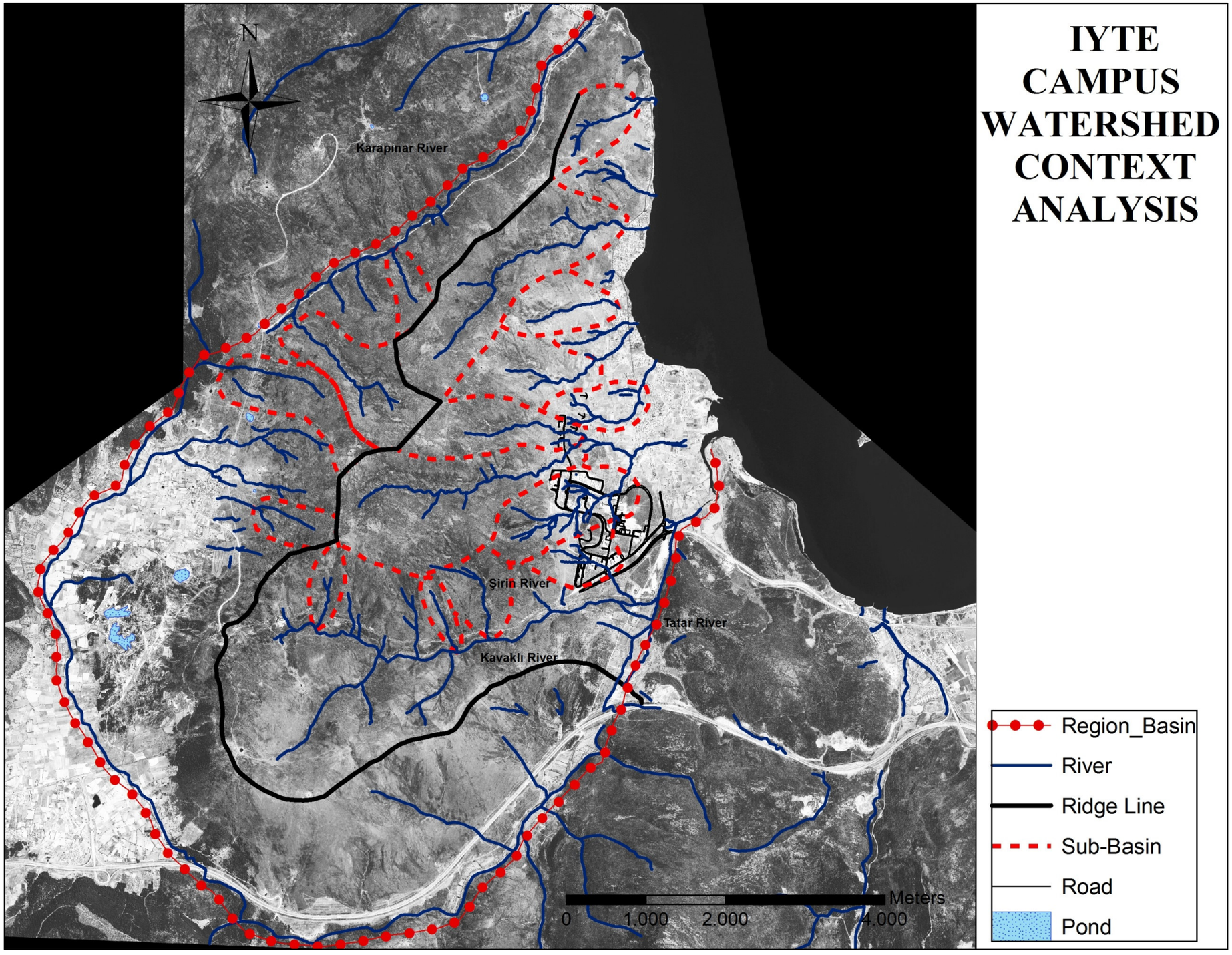


Figure 5.28. IYTE Campus Watershed Context Analysis

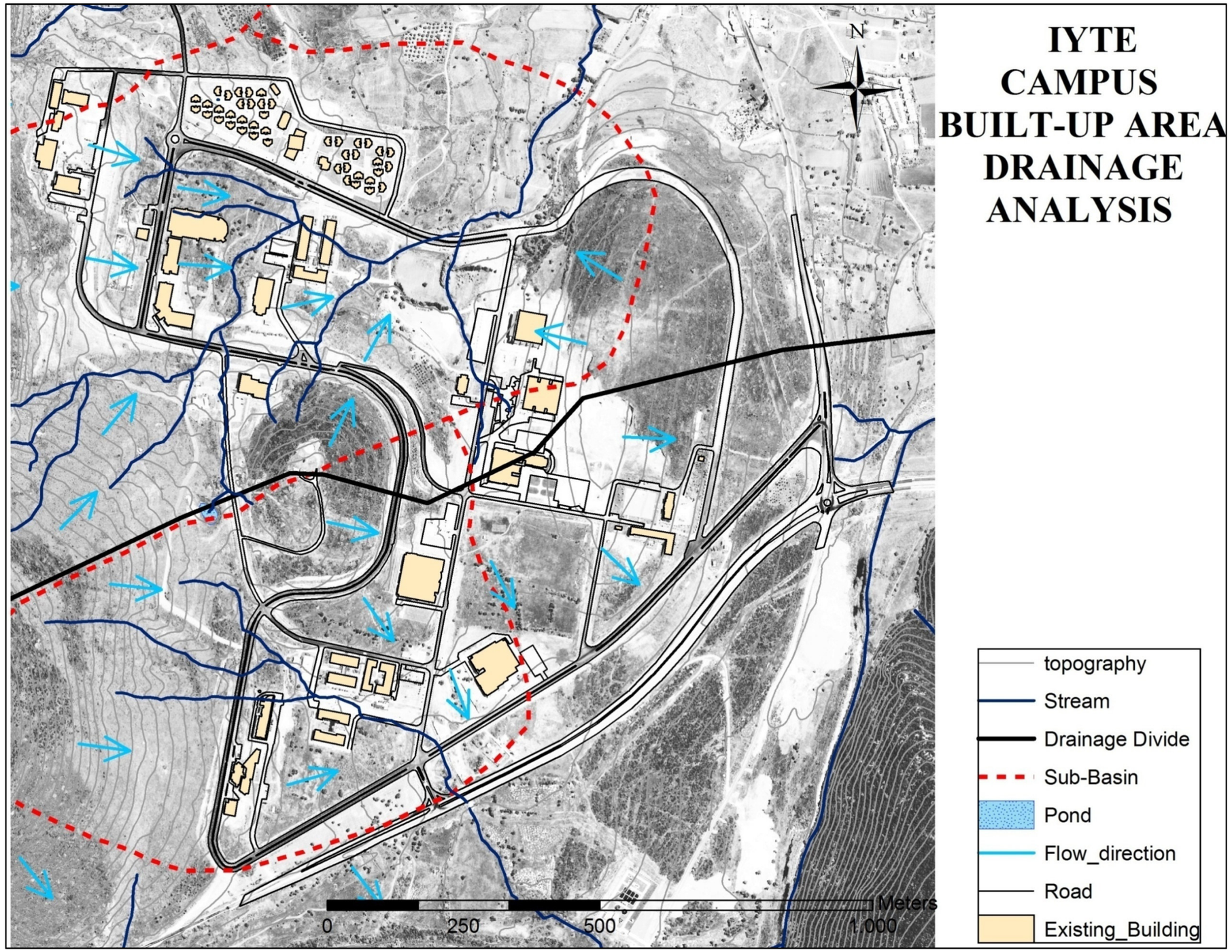


Figure 5.29. IYTE Campus Built-Up Area Drainage Analysis

The Campus surface and ground water level is analysed at some parts in a campus research project of “Investigating Surface and Underground Water Potential of Izmir Institute of Technology Campus” (Tayfur, 2010). The project aims to investigate the potential surface and ground water resources on campus to be independent of the water supplier. Infact the neighboring Gülbahçe Village supplies its potable water from natural ground water which is famous for its quality. To find the potentials for groundwater, measurements were taken in two wells to set their water levels on rainy days. Then the relation between ground water level and rain quantity were specified. Two study areas were selected. The First one is (Well 4) located nearby the faculty housing and the second one is (Well 1) located close to the Environmental Engineering Building (Figure 5.30).



Figure 5.30. Locations of Well 1 and Well 4 on Campus
(Source: Google Earth, 2005)

The measurements show that water levels of the wells are not stable. Generally, Well 1’s water level is 3,5 m but this level changes with rain and temperature. For example, it decreases to 2,5 m in summers. On the otherhand, Well 4 has 3 m water level but it is located at a higher point from the other well so its water level changes rapidly and can get dried up easily (Figure 5.31).

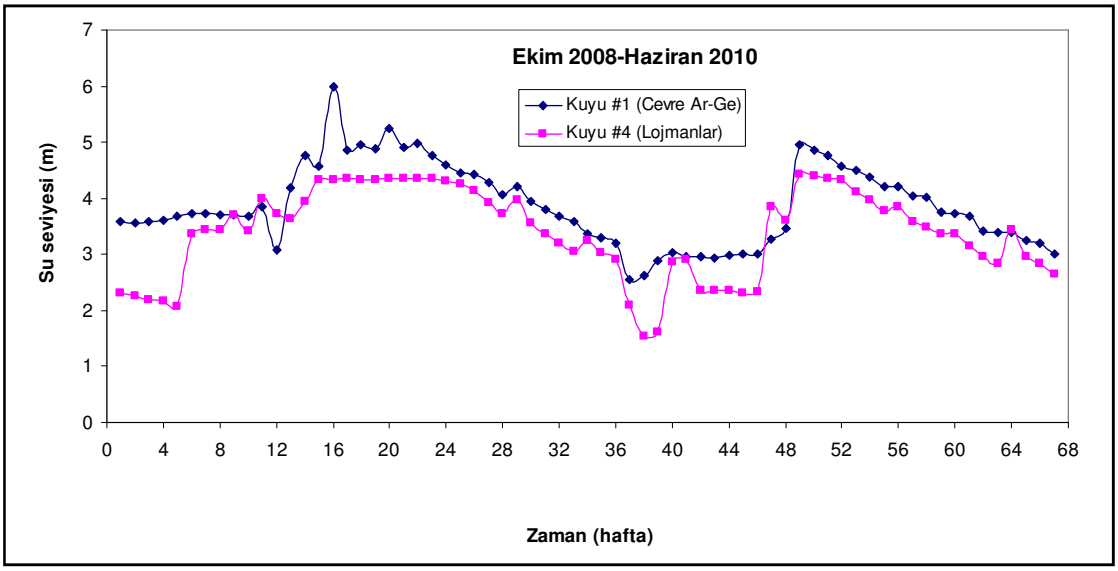


Figure 5.31. IYTE Campus Well Levels
(Source: Tayfur, 2007, p.16)

According to the results, the water levels change in wells and groundwater quantity is different on rainy days (Figure 5.32). The analysis were conducted from 2008 October to 2010 June. Figure shows the weekly values. Well water levels increase in rainy weeks but the level rises gradually because of infiltration and clay soil. Also, well levels become maximum at the fourth week of rain and infiltration continues along one month so wells are efficient to use in this period. Results show that, Well 4 is not proper for being a water supply for IYTE Campus because it is located on aquafier with cracks so its feedback area is not sufficient but Well 1 is proper. Well 1 provides 60 ton water for a day and can reach its previous capacity in 24 hours after water is used.

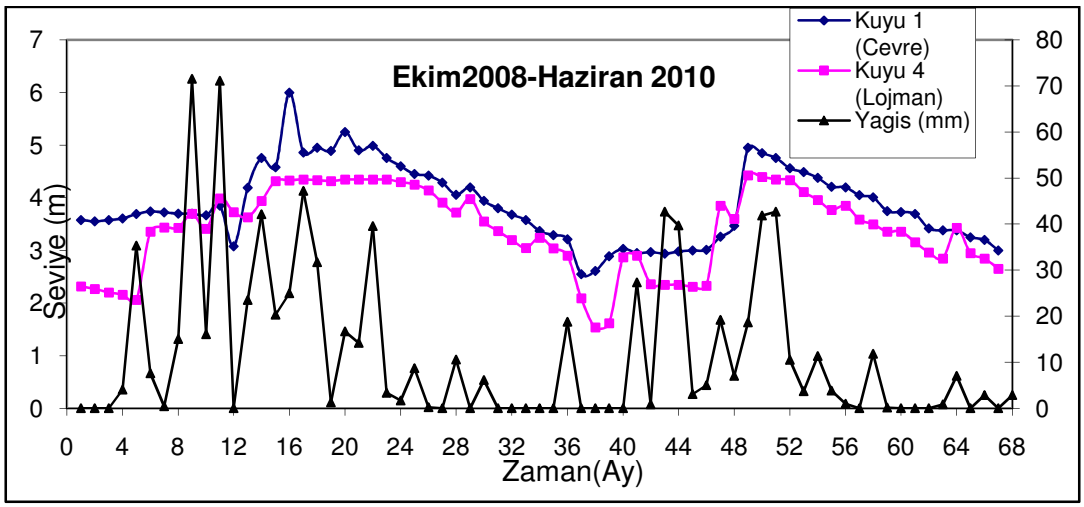


Figure 5.32. Weekly Water Levels at Wells According to Rainfall
(Source: Tayfur, 2007, p.18)

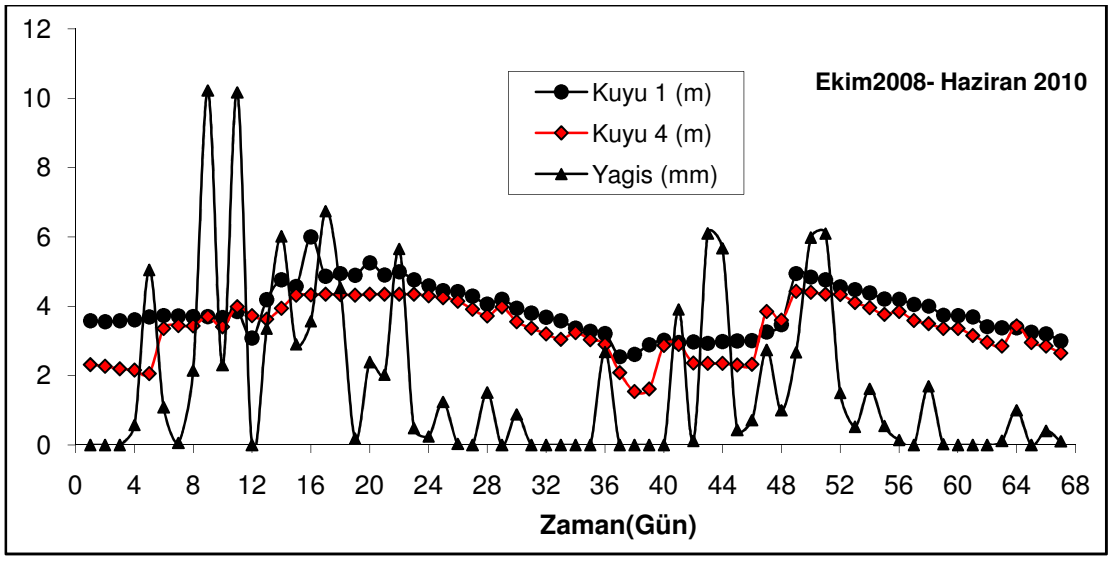


Figure 5.33. Daily Water Levels at Wells according to Rainfall
(Source: Tayfur, 2010, p.18)

On the other hand; two streams are analyzed for surface water potential. These streams are on north and south side of faculty housing. The flow quantities are measured and it was 150 lt/sc in January and February of 2010 but they are dry in summer. As a result of 130 mm rain, 150 lt/sec flow is provided by these streams and these rates show that streams can provide 13.000 m^3 flow quantity by day so this quantity will reach 160.000 m^3 yearly. To evaluate this potential, IYTE constructed a pond on the stream in the Fall of 2010 with the functions of water storage and recreation (Figure 5.34 to 5.36) (Tayfur, 2010).



Figure 5.34. Constructed Pond on Campus



Figure 5.35. Constructed Pond on Campus
(Source: Tayfur, 2010, p.20)



Figure 5.36. Constructed Pond on Campus
(Source: Tayfur, 2010, p.20)

The potable water resource for IYTE campus is provided by nearby Urla Municipality and problems with water supply and water quality have been experienced frequently also, this is not cost effective. There are two potable water tanks with a 300 and 1000 ton storage capacity. One of the water storage tank is located on the hilltop behind the central cafeteria which supplies the campus by providing flow to the campus by gravity and the other one is located far away from the built up area. Besides, dormitories' water supply is also supported by a well recently drilled near the faculty housing area on the North.

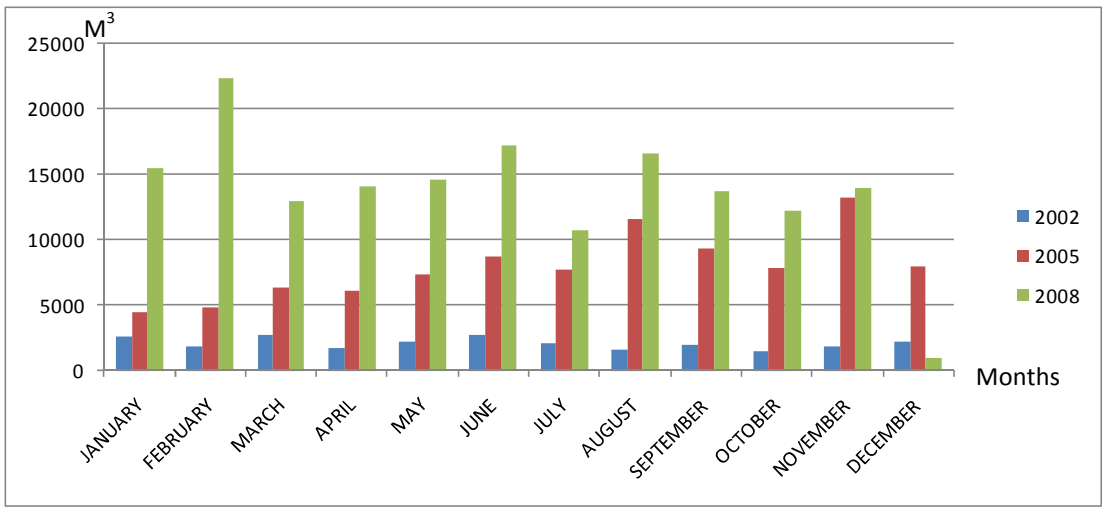


Figure 5.37. Water Consumption of IYTE Campus
(Source: Construction Department of IYTE, 2011)

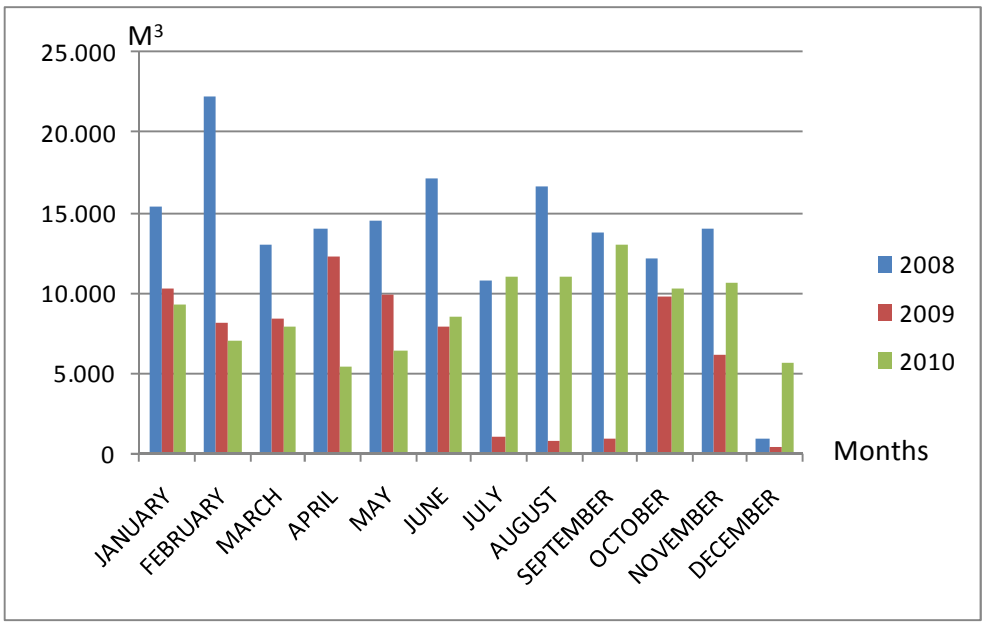


Figure 5.38. Water Consumption of IYTE Campus
(Source: Construction Department of IYTE, 2011)

It was seen from the graphs 5.37 and 5.38, the water consumption has been increasing as the campus has developed with construction of new faculty buildings and increasing campus population. The seasonal factors and vacations affect the consumptions. We can see from the graphs that in summer months because of summer holiday for students and academic staff the consumption quantity decreases but the consumption costs demonstrate not a stable increase because the (m^3) prices has changed so dependency for potable water is not cost effective (Figure 5.39).

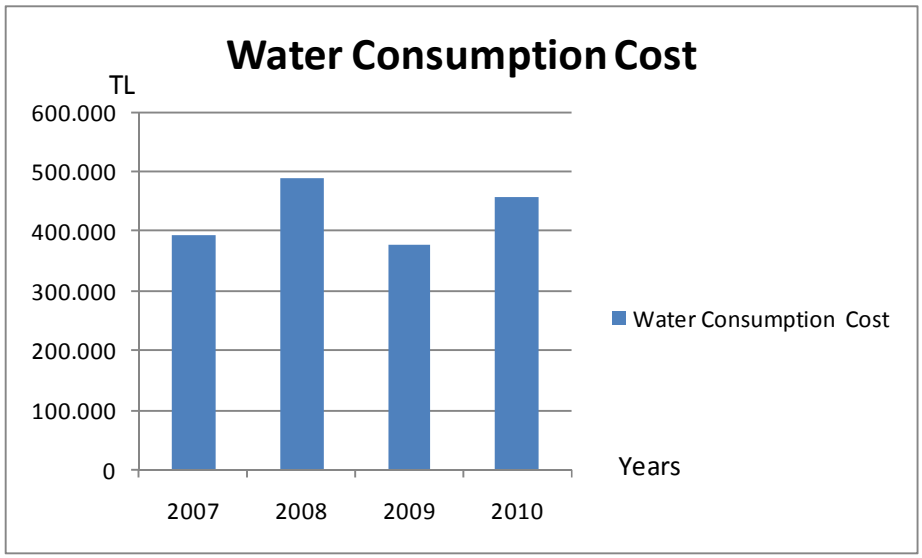


Figure 5.39. Water Consumption Cost of IYTE Campus
(Source: Construction Department of IYTE, 2011)

5.1.6. Infrastructure

Existing water related utilities are analyzed in the order of stormwater, potable water and treated water. Campus hasn't developed any comprehensive water resources and drainage master plan yet, but it is considered and planned to be developed with IZTEKGEB Infrastructure Plan (Iyte Bülten, 2010, September). At present, Campus has a conventional underground stormwater system and system is seperated from sewer system (Figure 5.50). The existing system is not compatible with nature and partial solutions generally give damage to environment.



(1)
Figure 5.40. Open Concrete Channel



(2)
Figure 5.41. Gutter and Channelized Stream



(3)
Figure 5.42. Gutter



(4)
Figure 5.43. Gutter



(5)
Figure 5.44. Concrete Channel



(6)
Figure 5.45. Concrete Channel to Gutter

There is not a continuous and natural drainage system on campus. Existing system is disconnected and partial, generally problems are solved at the source not related to whole system. The system drains the stormwater to the streams with the gutters or concrete open or semi-open channels (conveyance) without any filtration (Figure 5.40 to 5.45). The Figure 5.45 shows the end-of the system where collected stormwater is drained to stream. This is not end-of whole campus stormwater system, only includes the area where the Sports Building, the Computer Engineering Building

and the Library are located. These buildings' rooftop and surface runoffs are drained to there. Generally, these partial solutions are applied to whole campus built-up area.



(7)
Figure 5.46. Conveyance



(8)
Figure 5.47. Conveyance



(9)
Figure 5.48. Open Concrete Channel



(10)
Figure 5.49. Open Concrete Channel

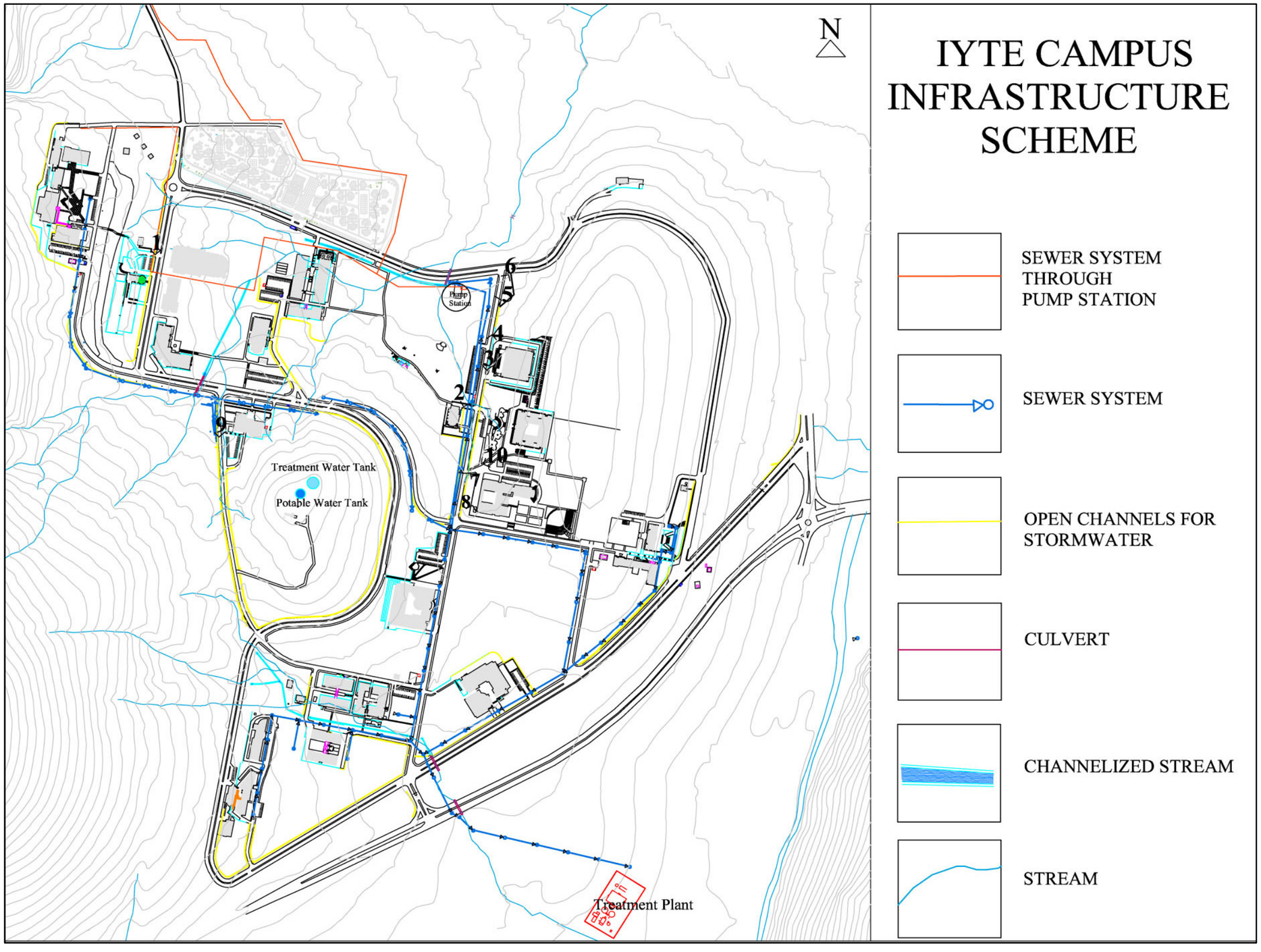


Figure 5.50. IYTE Campus Infrastructure Scheme

Two of the streams have been channelized in the development process of IYTE Campus. One of them is on the North Basin, the other one is on the South Basin. The aim of the channellization is to prevent flooding because in the past these streams were not taken into consideration at the development stage but according to the DSI Report (1993), the south basin stream should be channelized because of flood risk but the north basin stream do not need to be channelized. There was a flood at Faculty of Science and the groundfloor was flooded because of heavy rain and changed stream course in 1996.



(1)
Figure 5.51. Channelized Stream on North Basin



(2)
Figure 5.52. Channelized Stream on North Basin



(3)
Figure 5.53. Channelized Stream on South Basin

The roof of the buildings are impervious and don't have any water storage systems. Downspouts of the building roofs are disconnected. Generally, the rainwater from the downspouts of the roofs drained to impervious surfaces or planted areas, but the soil type is not proper for infiltration so plant areas do not provide groundwater recharge (Figure 5.54 to 5.57).



(4)
Figure 5.54. Disconnected Downspout at Faculty of Architecture



(5)
Figure 5.55. Disconnected Downspout at Faculty of Architecture



(6)
Figure 5.56. Disconnected Downspout at ARGE Building



(7)
Figure 5.57. Disconnected Downspout at Computer Engineering Building

Besides, some of the recently constructed buildings such as library and buildings that are on construction such as biology and mathematic, the downspouts are not disconnected. They are directly connected to the piped infrastructure system so rainwater is drained to streams (Figure 5.58 and 5.59).



(8)

Figure 5.58. Connected Downspouts



(9)

Figure 5.59. Connected Downspouts

On the otherhand, the vehicle roads, pedestrian paths, parking areas, and plazas are made of hardscape surfaces which are impervious. Because of the impervious areas and inefficient and undermaintained stormwater infrastructure system, the potholes are filled with rainwater on rainy days and puddles occur on surfaces (Figure 5.60 to 5.72).



(10)

Figure 5.60. Stone Surface Puddles

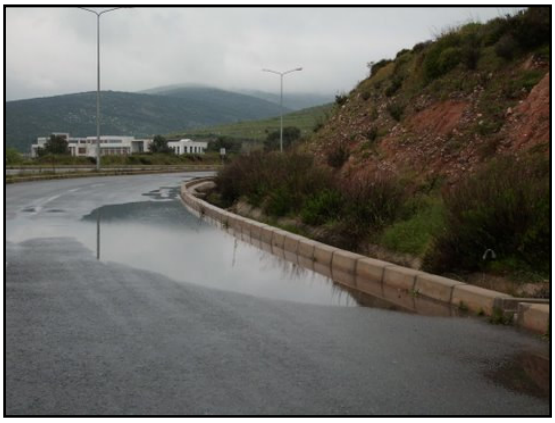


(11)

Figure 5.61. Marble Surface Puddles



(12)
Figure 5.62.Stone and Asphalt Surface Puddles



(13)
Figure 5.63. Asphalt Surface Puddles



(14)
Figure 5.64. Asphalt Surface Puddles



(15)
Figure 5.65. Stone Surface Puddles



(16)
Figure 5.66. Asphalt Surface Puddles



(17)
Figure 5.67. Asphalt Surface Puddles



(18)
Figure 5.68. Asphalt Surface Puddles



(19)
Figure 5.69. Asphalt Surface Puddles



(20)
Figure 5.70. Asphalt Surface Puddles



(21)
Figure 5.71. Asphalt Surface Puddles



(22)
Figure 5.72. Asphalt Surface Puddles

Also, erosion occurs at some part of the campus because of imperviousness of surfaces on rainy days (Figure 5.73 and 5.74) and some leaky surfaces come out at some parts even when there is no rain (Figure 5.75 and 5.76). Generally, these surfaces are covered with water both on dry and wet days. Besides, partial solutions are applied at their source on campus for example in slope areas concrete drainage ways are constructed to provide surface runoff due to site disturbance after construction (Figure 5.77 and 5.78) but these are the solutions that disturbe the environment.



(23)
Figure 5.73. Erosion that occurs at Faculty of Science



(24)
Figure 5.74. Erosion that occurs at Faculty of Architecture



(25)
Figure 5.75. Leaky Surfaces



(26)
Figure 5.76. Leaky Surfaces



(27)

Figure 5.77. Concrete Drainage Way



(28)

Figure 5.78. Concrete Drainage Way

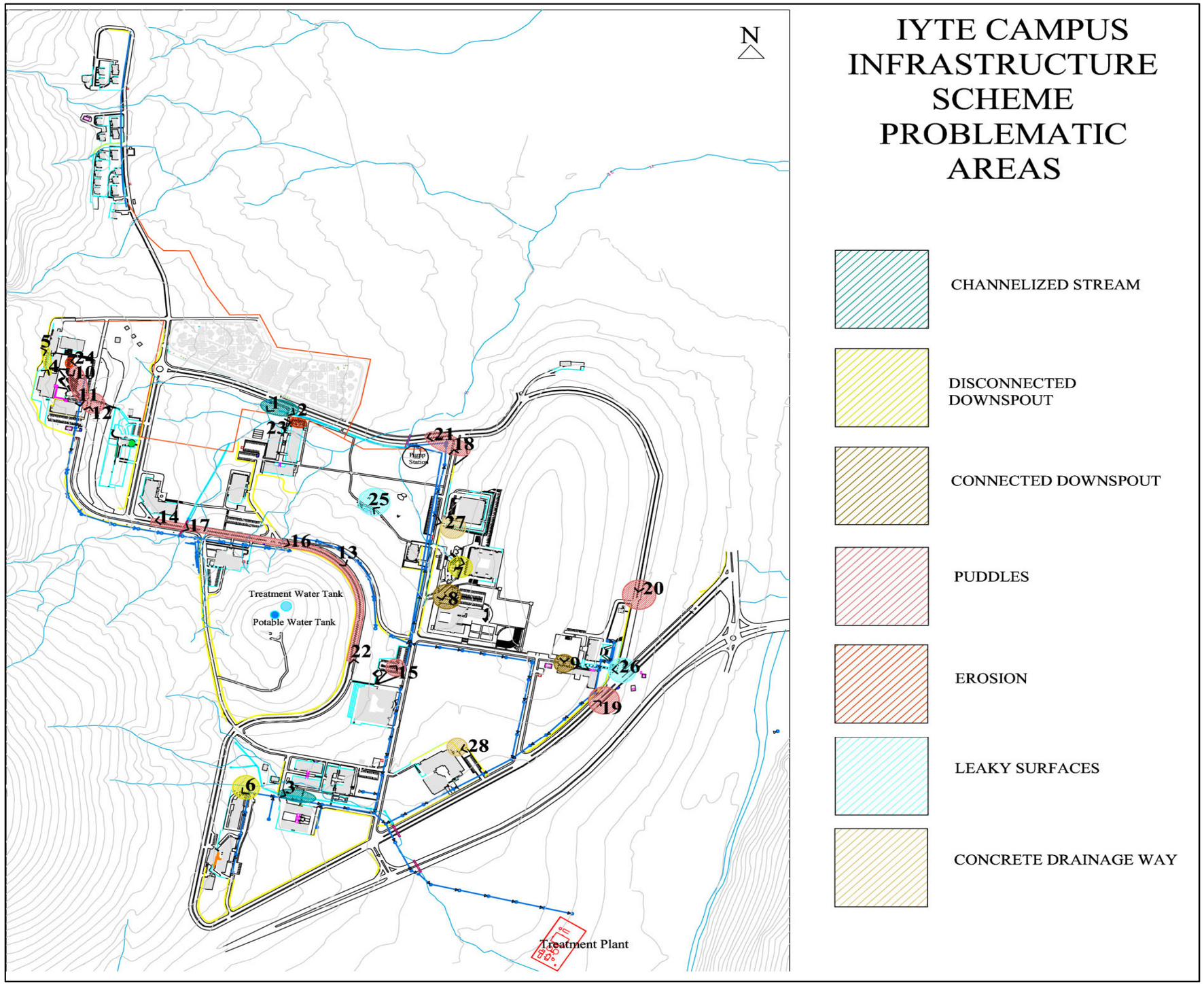


Figure 5.79. IYTE Campus Infrastructure Scheme Problematic Areas

The sewer system of campus is divided into two lines because of the slope. As we see in Figure 5.50, there are blue and red lines. Red lines carry the sewege from Faculty Housing, some part of Faculty of Architecture and Faculty of Science through a pump station. The blue lines carry sewer from other parts of campus. Red lines pump collected sewege through blue lines and lastly both of them are directed towards treatment plant of campus. Treated water is stored at 750 ton capacity open tank (Figure 5.80). Recently, treated water is started to be used for drip irrigation of campus plants when needed (Figure 5.81 and 5.82). Tank capacity for irrigation is sufficient for ten days. The system provides to reduce potable water consumption and especially reduce labor force in summer.

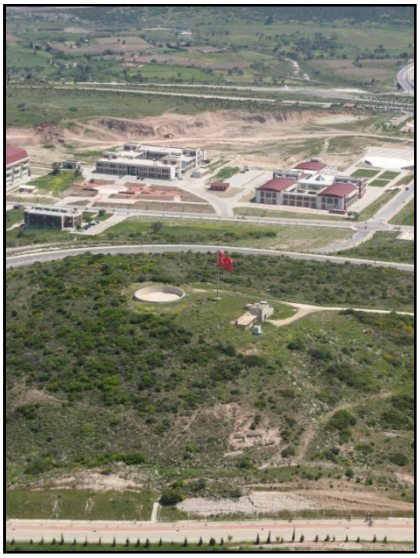


Figure 5.80. Water Tanks on Campus
(Source: IYTE Archive, 2011)



Figure 5.81. Treated Water



Figure 5.82. Drip Irrigation System

5.1.7. Campus Development History and Master Plan

Izmir Institute of Technology Campus is firstly designed by Italian Architects Luigi Pisciotti and Uberto Siola (Figure 5.84). The initial plan arranged the administrative and academic buildings on both sides of the main alley. The pedestrian roads were designed in a girid system and circulation network was thought as outer vehicular road and this road was supported by dead-ends through campus buildings, but later this plan became insufficient so master plan was changed.

In developing stage of Campus, firstly Faculty of Architecture buildings are constructed on the highest elevation so Architecture Faculty is the area that is effected the most from climatic conditions like wind speed. This condition also affects the accessibility and connections among other campus buildings. Later, other faculty buildings started to be constructed on low points but the connectivity and the accessibility of the buildings on campus is low (Figure 5.83).



Figure 5.83. Campus Development Process (1998)
(Source: IYTE Archive, 98)

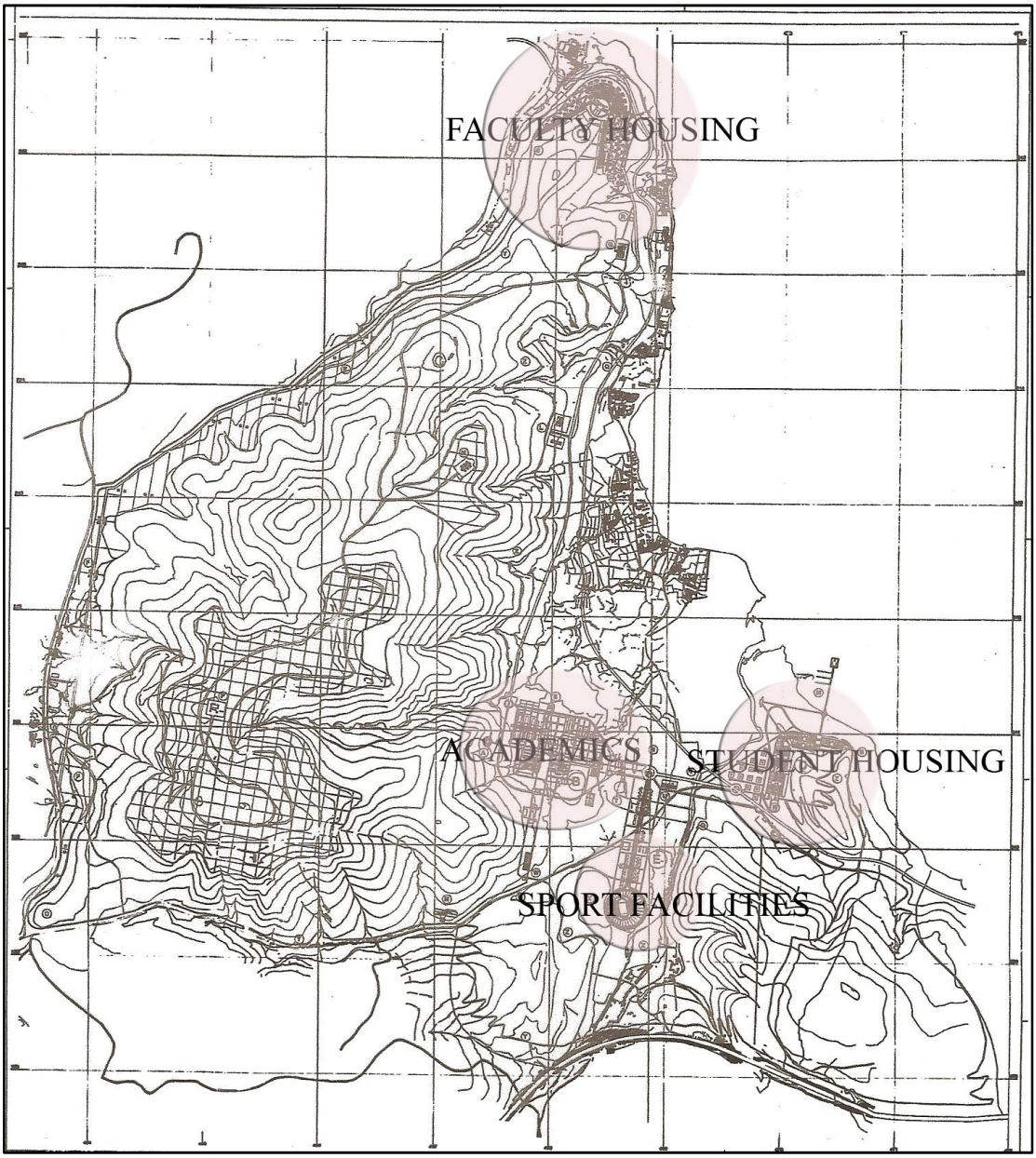


Figure 5.84. Initial IYTE Campus Plan
(Source: Cemal Arkon's Personal Archive)



Figure 5.85. IYTE Campus Revised Plan
(Source: Ağan, 2000)

The initial master plan has gone through several changes throughout time. Firstly, the circulation routes were changed. According to vehicular and pedestrian roads, the location of buildings and their orientations became different. Then, the student housing has been relocated to a location near the academic buildings from its first location by the geographical fault and the geothermal springs. The faculty housing also has been relocated near the current academic buildings from its remote location on the periphery of the campus area by the sea. Another change was in the natural environment. One of the streams has been changed its course due to development of Faculty of Science building. The designers of the first master plan describe the campus site as "The site has a great scenic beauty and uncontaminated environmental condition with a view of the sea along the entire northern side" (Pisciotti, 1994). Unfortunately this plan did not take into account several significant attributes such as topography, natural environment, location of the high voltage transmission line and the geographical fault near student housing. Therefore this had to be changed during implementation. The Faculy of Architecture has prepared a Master Plan which has been followed so far.

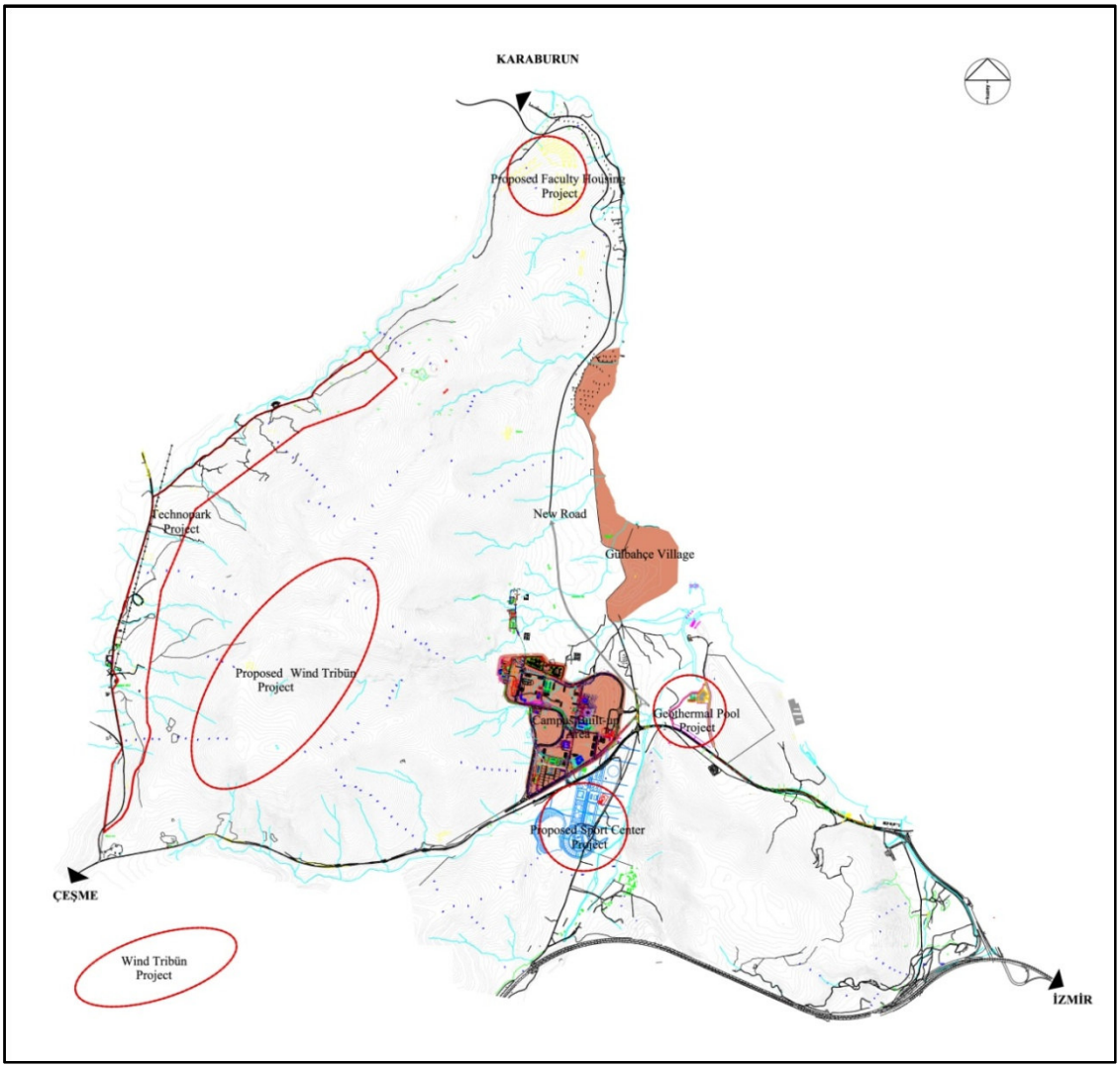


Figure 5.86. IYTE Campus Existing and Proposed Projects

In the development process of IYTE Campus, some projects, which are sport center project, geothermal pool project, wind tribüne project, technopark project, faculty housing and student dormitory project, are developed for campus. These projects' proposed locations are specified on campus master plan but not any application yet except for wind tribüne project, faculty housing and dormitory project with their new locations besides proposed locations (Figure 5.87).

5.2. Evaluation

The campus stream resources and their watershed areas provide an underlying foundation for this study. Therefore, to the maximum extent possible, stormwater and landscape management decisions and applications should reflect the watershed conditions and be carried out to protect and restore these resources overtime. The development of this Stormwater Management Plan has several components including; a review of existing campus stormwater conditions that include site-specific locations of problems and opportunities and specification of the areas of localized flooding, impervious surfaces, inefficient landscape designs. Then, evaluation of constraints in the campus. Especially, landscape with consideration of existing trees, plants, soil type and other conflicts like topography, climate, man-made interventions to nature are identified to specify the opportunities to integrate stormwater techniques and retrofit the existing campus and last develop case studies for application of Stormwater Best Management Practices.

Evaluation process consists of natural site features and manmade interventions of Infrastructure and Master Plan. SWOT analysis is developed for identification of the Strenghts, Weaknesses, Opportunities and Threats of the IYTE Campus Analysis (Table 5.2). When started from Natural features, it shows that , natural gradient provides an advantage for natural water flow and changing slope and elevation help to determine basin areas. **Topography and slope analysis** is important for IYTE Campus because this provides opportunity for BMPs practices and help to determine their locations on campus. The **vegetative cover** serves an opportunity because campus native plants provide the reduction of potable water consumption also greenhouse provide an advantage to grow campus plants locally and it is cost effective. However, a recent malting application for the surrounding of all faculty buildings is not water and cost efficient because these turf areas needs great amount of water and maintenance. On the otherhand, **geological analysis** shows that campus surface water which is currently drained to streams can be stored in agglomerate which are located under tufas. **Soil analysis** is another important factor to be considered for permeability, because soil groups determine their permeability performance. Infiltration rates are controlled by soil surface conditions. Generally, there are four hydrological soil groups. These soil groups are A, B, C and D. Soil A has the best infiltration rate and D is the least so IYTE

Campus should be in D category because campus soil type is clay and clay soil has low infiltration capacity. However, this weakness provides an opportunity for ground storage like ponds, wetlands, bioretention areas. **Climatic features** of IYTE Campus demonstrate decreasing rainfall rates that can be a threat for providing alternative water resources and hot and dry summers are also threat for surface basin areas to become dry. Besides, strong winds cause evapotranspiration of surface waters. **Watershed and water resources analysis** specify the channelized and re-routed streams. Two streams were buried into concrete channels and one of the stream course was changed. This channelization approach is not proper for the natural drainage and sustainability assets because concrete channels are not pervious, permeability is important for the storage but the stream which is channelized near the Faculty of Science should not be channelized according to the DSI Report (1993). Naturalized streams will provide an opportunity for an aesthetic and recreational function also groundwater opportunities that is provided from wells can help to become independent for potable water.

Second part of evaluation is man-made interventions. Firstly, the **Master Plan** shows that campus has scattered layout with a high rate of site disturbance. The natural assets were not considered in development stage and scattered development damaged natural landscape in the past. The Campus Area is on 2. Degree Natural Preservation Site so the buildings have been built with two floors. Therefore, scattered development is inevitable. Inaccesibility is another problem that increase vehicle dependency. So, future developments should be compact because of the sustainability assets and infrastructure cost. Also, imperviousness ratio will increase with expansions and new additions like buildings, roads, pedestrian paths, parking lots and plazas. According to the calculations the existing campus has a 4.5 % imperviousness ratio. At present this ratio can be considered low but campus has large built up area and many buildings have not been constructed yet. The future developments will increase this ratio further away from the current level. The Campus Development plan shows how this ratio will increase (Figure 5.92). The table below compares the existing and future construction areas and the changing ratios.

Table 5.1. Comparison of Impervious/Pervious Areas of IYTE Campus

Impervious/Pervious Areas of IYTE Campus	**Existing**	**Future**
Total Campus Area	35.000.000 m^2(3500 Ha)	35.000.000 m^2(3500 Ha)
Built Up Area	1.541.239 m^2(154,1 Ha)	1.541.239 m^2(154,1 Ha)
Parking Lot Area	15.978 m^2(1,5 Ha)	26.744 m^2(2,6 Ha)
Building Floor Area	52.200 m^2(5,2 Ha)	88.167 m^2(8.8 Ha)
Building Construction Area	136.356 m^2(13,6 Ha)	218.767 m^2(21,8 Ha)
Total Woodland Area	437.002 m^2(43,7 Ha)	467.802 m^2(46,7 Ha)
Natural Area	1.306.000 m^2(103.6 Ha)	950.000 m^2(95 Ha)
Pervious Area Ratio	%95.5	%85.4
Impervious Area Ratio	%4.5	%7.4

Current total building construction area is 13,6 ha and total woodland area is 43,7 ha. These numbers will increase, once all the buildings are constructed with added impervious pathways and parking lots. According to the campus development master plan, campus built up area will increase because dormitory area will be expansion and the future population is determined near 10000 people. Total areas will increase and the ratios will change with new developments on campus (Table 5.1).

On the otherhand, the existing **Infrastructure analysis** (Figure 5.51) demonstrates campus has conventional stormwater system seperated from sewer system. This can provide opportunity to convert existing conventional sytem into green infrastructure system easily. There is not a continuous stormwater system, solutions are partial at source. Stormwater runoff is mostly directed to river that causes water pollution, but as global warming increase year by year, the water resources will be decreased so alternative water resources should be considered. Stormwater or rainwater is an essential water resource for campus. IYTE Campus is located in a mediterranean climatic zone so winter is generally rainy and rainfall quantity changes monthly. So, on rainy days, stormwater is a good water resource for IYTE campus whereas summers are hot and dry, so air conditioner condensate is another alternative water resource to be considered to store and reuse. Besides, surface runoff is drained to stream without filtration so this is a threat for water pollution. As a strenght, sewage water is treated for campus plant irrigation with an opportunity of reduce potable water use and drip irrigation method is used on campus, this strategy is cost effective for laborforce and reduces the water consumption. At the present downspouts of most of the buildings are disconnected and therefore rainwater from rooftops is drained to the open areas either pervious or impervious rather than directly being connected to the stormwater system

with an exception of the Library Building. Most of the campus buildings are suitable for green roof application. They will provide to reduce the runoff quantity and reduce the impervious ratio of the campus. On the otherhand, there are some simple applications to be evaluated as practices for stormwater management. Firstly, treated water is used for irrigation so potable water use for irrigation is reduced. Beside, curb-cuts are used on pedestrian path, which connect the Faculty of Science through the main pedestrian axis of campus to the sport complex; to drain surface runoff towards pervious area (Figure 5.87 and 5.88) and some pervious surface application on slope points on campus (Figure 5.89 and 5.90).



Figure 5.87. Curb-cuts Application



Figure 5.88. Curb-cuts Application



Figure 5.89. Pervious Slope at Cafeteria



Figure 5.90. Pervious Slope at Faculty of Science

Besides, some of the applications for surface water storage like recently constructed pond close to Faculty Housing is not environment-friendly because concrete material is not pervious and it is neither functional and nor aesthetic. It is dry most of the year.

Campus is dependent for potable water supply and gets its water from Urla at high costs. Also, the thermal water resource on campus can be used as a clean energy resource but the temperature of the water is not sufficient to heat the campus buildings and the residential areas on the present source but the studies will continue for investigating another resources because thermal water is a good source for energy efficiency.

As a result, developments and applications on IYTE Campus mostly cause disadvantages to have sustainable water management system. There are some positive practices but not enough because these are partial solutions not comprehensive campuswide. Some of the existing practices of growing native olive trees and lentiscus (sakız) seedlings on campus green house, and afforestation with these, production of olive oil, wind tribunes and paper recycling are considered as promising initial steps toward campuswide sustainability of IYTE.

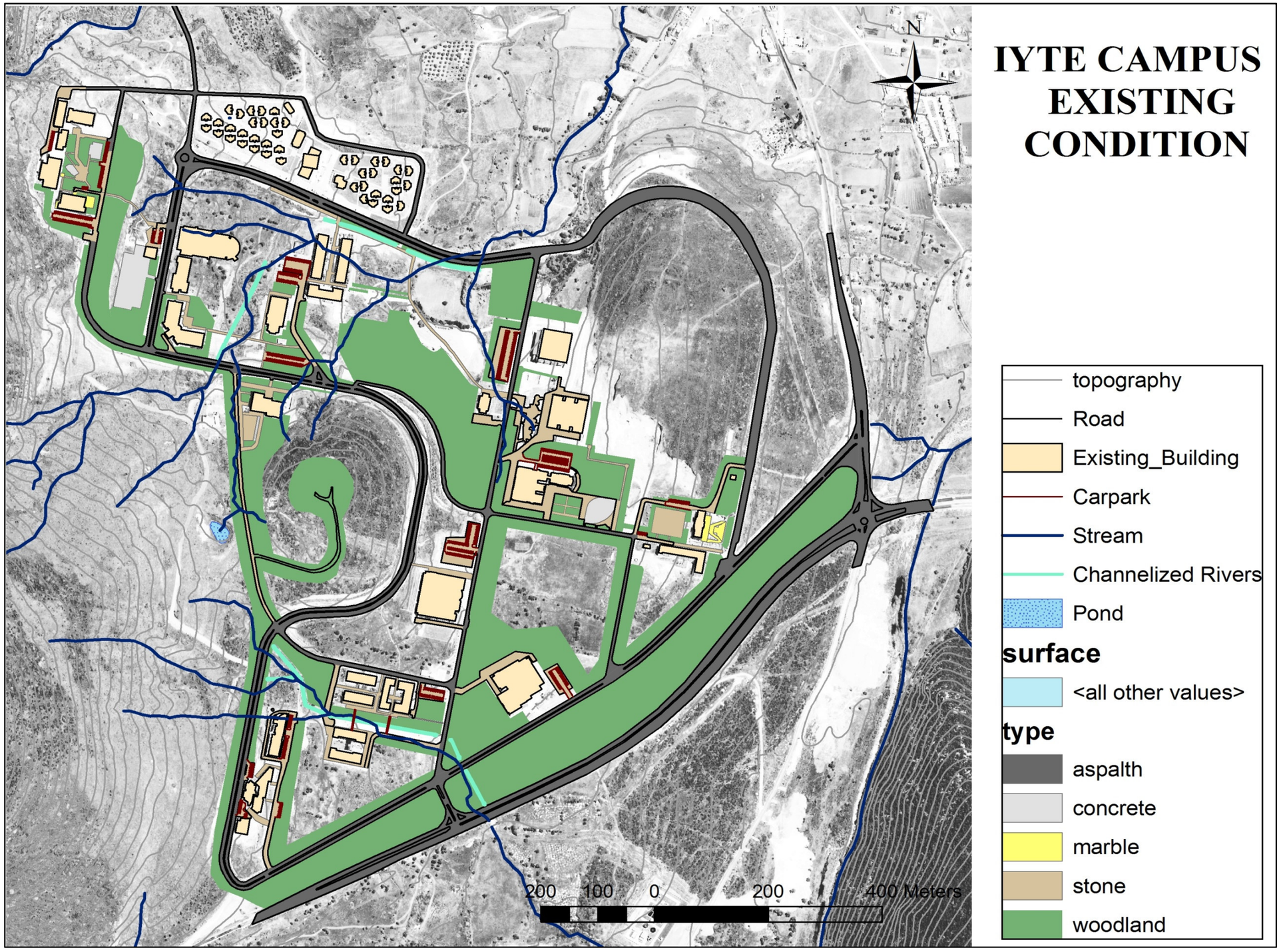


Figure 5.91. Existing Condition of IYTE Campus

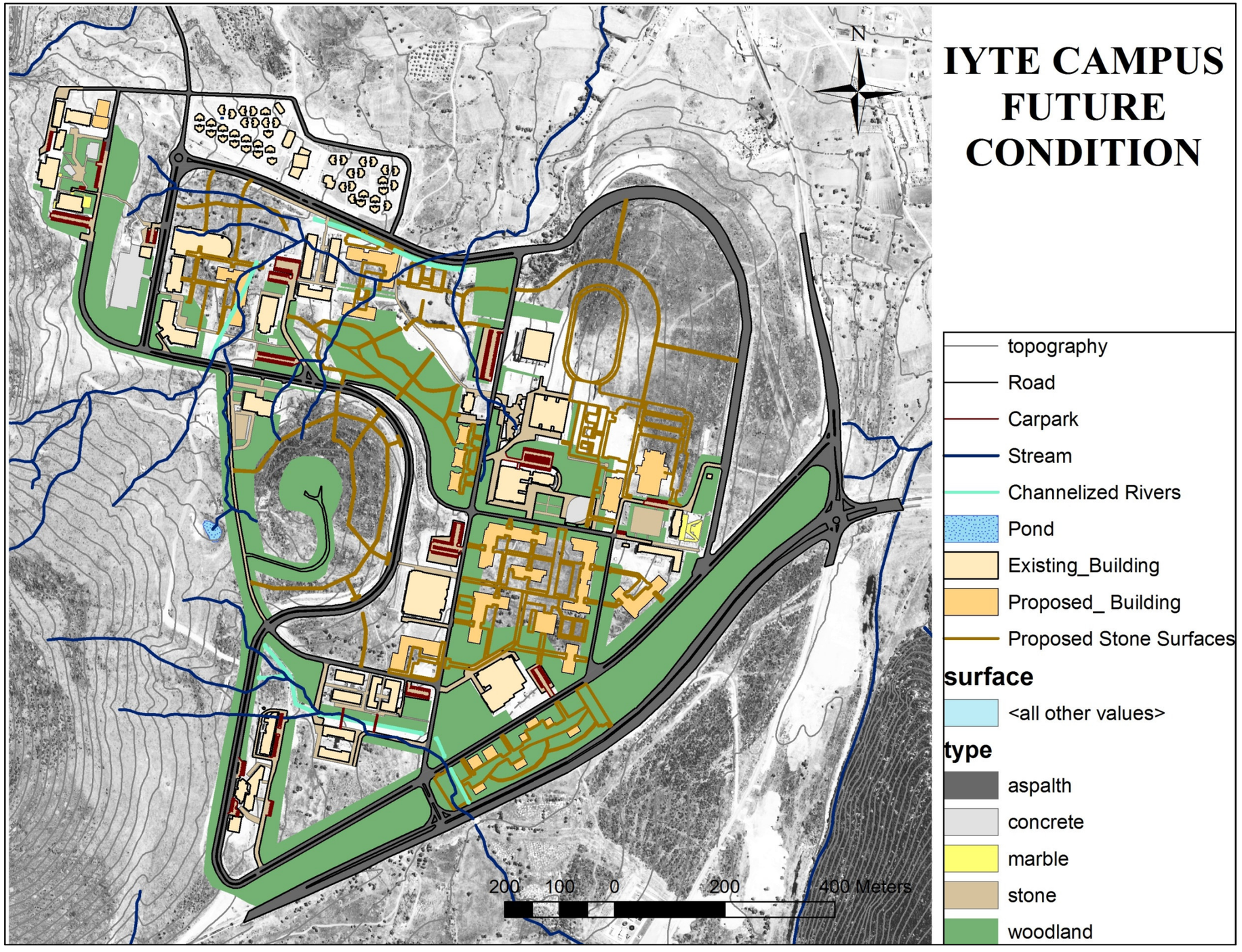


Figure 5.92. Future Condition of IYTE Campus

Table 5.2. SWOT (Strenghts,Weaknesses,Opportunities and Threats) Analysis

	STRENGHTS	WEAKNESSES	OPPORTUNITIES	THREATS
uilt Environment (Physical and Aesthetic Properties)	*Seperate Sewage and Stormwater System *Sewage Water Treatment *Use of Recycled Water for Irrigation *Small Scale Surface Runoff Drainage Solutions, like curb-cuts, downspout connections *Recent Investigations for Surface and Underground Water Potentials	*Scattered Development *Disposal of Untreated Stormwater into the River and Gulf *Partial Drainage Practices at the Source *No Continuous Drainage System at the Present Network *Impervious Drainage Channels *Disconnected Downspouts of Building Roofs *High Ratio Impervious Surfaces	*Seperate Drainage System Provide to Return Green System Easily *Treated Sewage Water Provide Use of Less Potable Water Consumption For Irrigation * Cost Effective Irrigation System *Vast Amount of Space for Retrofit BMPs	*Inadequate Data(Soil Analysis, Grading Analysis, Water Resources Analysis, Meteorological, Runoff Rates for Campuswide) *No Stormwater Management and Landscape Plan *Effects of Climatic Conditions to BMPs
Natural Environment (Fauna, Flora,Air and Water)	*Non-Urban Site *Changing Topography *Natural Landscape *On-Site Surface and Groundwater Resources	*Channelized and Re-routed Streams *Soil Type with Low Infiltration Rate *Inefficient Landscape Design	*Natural Slope and Elevation Provide Natural Flow and Setting Stormwater Basins *Native Plants and Trees *Geological Features that Allow for Underground Storage *Independency of Potable Water	*Site Disturbance(Erosion, flooding, Re-routed Stream, Channelization of Streams) *Water Quality Degradation *Inappropriate Soil Type for BMPs
Socio-economic Environment	*Locally Grown Plants in Greenhouse of Campus *Use of Drip Irrigation	*Dependence of Potable Water Supply	*Cost Effectiveness of Local Production of Plants *Cost Effectiveness of water consumption	

5.3. Best Management Practices (BMPs) for IYTE Campus

A vision of IYTE Campus for sustainable water management is to protect the campus site character and environmental quality, produce green and environmentally sustainable structures with expression of campus as an incubator for dynamic emerging technologies and water resources related research that reinforce IYTE as a role model for other campuses and cities in İzmir and Turkey. University administration should make stormwater an issue on campus and create a leadership entity in solving ecological issues both in principle and practice where students can find themselves in the topics of their study at every side of their daily lives.

Izmir Institute of Technology has not developed any water resources management plan or any related design strategies in the development process. Thus, design and applications in campus are not compatible with natural resources and damage nature. To prevent these, specific strategies should be identified and plans should be developed according to the strategies. These strategies are identified in accordance with the campus natural characteristics such as climate, topography, soil, vegetation and water resources. Therefore, what is facing the University is to mitigate the impact of its proposed future development. To aim low environmental impact on campus, some limitations about Stormwater Management and Best Management Practices are identified which are clay soil that cause low infiltration rate of soil, climatic conditions with low rainfall capacity and high wind speed that cause to construct detention basin areas and increase the evapotranspiration of plants and scattered development that cause disconnected solutions. Thus, a Stormwater Management Plan has to be developed to help the University explore how a "restorative approach" can be applied in concert with sound stormwater management practices that seek alternative practices and strategies to create a sustainable campus that conserves natural resources, restores environmental quality, and produces an aesthetically pleasing campus environment. This Stormwater Management will reduce the water and soil pollution on campus, because existing system drain the surface runoff through the streams and bay without any infiltration. Therefore, Campus Sustainability Office should be established as it is in many other universities to conduct these approaches and there should be water resources research center for academic researches and

technological developments on campus so university can become a laboratory both for Izmir and Turkey.

The proposed Stormwater Management Plan defines an alternative approach to conventional stormwater management with describing Best Management Practices (BMPs) that will improve the impacts of stormwater runoff generated by site disturbance and constructions. The Stormwater Management Plan of IYTE Campus aims to demonstrate the strategies for current and future development with the intent of managing all stormwater on site. Firstly, IYTE administration should increase awareness to interrelation between the groundwater, rainfall and stormwater runoff and develop strategies with considering this interrelation. Actually, the goals for stormwater management will provide transition from end-of-pipe stormwater systems to sustainable approaches.

The goals of Stormwater Management Plan for campus are developed according to Leed for Neighbhorhood Development (Leed-ND) Rating System which aims to create sustainable living areas (Appendix B). The strategies in Leed-ND are taken as a guide for IYTE Campus. Leed-ND Rating System Categories are grouped by "Smart Location and Linkage", "Neighborhood Pattern and Design", "Green Infrastructure and Buildings" and "Innovation and Design Process". The goals of the Stormwater Management Plan for IYTE Campus are, conserving water, managing stormwater as an opportunity and amenity not a problem, reducing impervious surfaces, managing campus stormwater by joining the capacity of topography, soils and plants, reducing water consumption with protecting water quality, reducing water runoff rate, improving natural habitats, preventing soil erosion, restoring streams, implementing designs which allow for stormwater to be reused on-site. To achieve these goals, the structural and non-structural techniques are identified with specific locations on campus (Table 5.3). This study develops a conceptual scheme which will be a guide for Campus Water Resources Master Plan (Figure 5.94).

Table 5.3. Structural and Non-structural BMPs for IYTE Campus

Structural Practices	**Non-Structural Practices**
Natural Drainage Ways(Swale,Planter Box,Conveyance)	Xeriscaping Landscape
Basin Areas(Ponds,Wetlands,Filter Basins,Bioretention)	Pest Management
Pervious Pavement	Water Quality Controls
Underground Storage Areas	Composting of Plant Waste
Drained Roofs (Downspout Disconnection)	Mulching for Plants
Restoration of Channelized Streams	Minimize Impervious Areas
Use of Air Conditioner Condensate	Local Production of Seed
Greenroof Application	Reduction of Grass Areas and Conversion to Native Grass
	Forestration
	Desalination of Sea Water

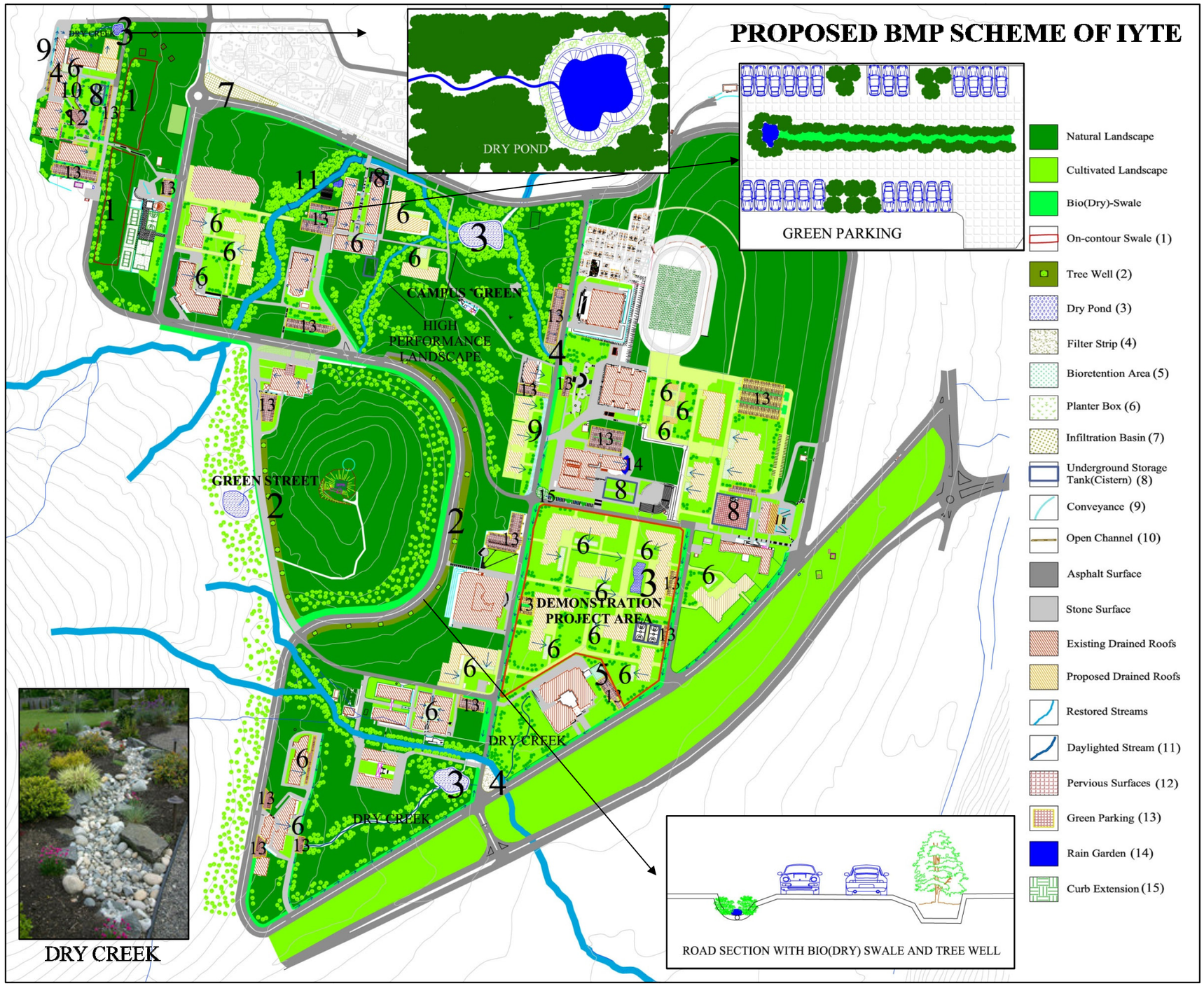


Figure 5.93. Proposed BMP Scheme of IYTE Campus

Best Management Practices are developed to capture, store, reuse and infiltrate stormwater on site. For capturing the stormwater, there should be a transition from the traditional to natural drainage system on campus. When campus is evaluated as a whole, it has natural streams and slope of campus provides an advantage for natural water flow. Thus, natural drainage system and basin areas such as ponds, infiltration basins or detention basins based on their function can be created easily.

Stream Re-Naturalization: Two of the streams were channelized in the past so firstly, channelized rivers will be rehabilitated and re-naturalized. Restored rivers will provide new habitats and they will be added to natural drainage system so there will be water continuity on site with performance landscape. The stream that flows nearby the Faculty of Science, the primary waterway on campus, serves to link the academic uses within the campus to recreational uses and beyond to the agricultural lands and the village further to the north. The stream was re-routed (changed its course), straightened and restrained into a concrete box by channelization and elimination of meanders and existing vegetation. As a result of these man-made interventions, the stream has been lost as a natural feature and amenity for the campus. Therefore the channelized stream should be re-naturalized and restored in order to recapture this "lost" natural resource and to reclaim an amenity for the campus community again. It is recommended that the natural setting of the channelized stream should be re-created by returning to its natural state. To do this, the concrete box should be removed, and a meandering course should be created by approximating the original path of the stream near the Faculty of Science. This re-naturalized and restored stream corridor will become/constitute the 'centerpiece' of the campus, **'The Campus Green'**, which offers aesthetic and environmental benefits for the University community as well as the community neighborhoods located within the watershed. The Campus Green will consist of recreational uses along the restored stream and a stormwater detention pond in conjunction with active and passive recreation through a jogging /biking trails system and the festival area. In addition to these benefits, the arrangement allows the Campus Green to become an outdoor classroom for students and an area for recreation and pedestrian circulation between the west part and the east part of the campus.

Increased Perviousness: On-site infiltration of stormwater is crucial for recharging groundwater level but IYTE Campus has a low infiltration capacity soil so instead engineered soil can be adopted at some parts of campus, where the ground storage cisterns are located, and pollutants can be easily removed from runoff to improve

groundwater quality. Especially, parking lots and plazas should be converted into pervious surfaces. Land cover is important to determine how much runoff is produced on campus. Imperviousness plays an important role to reduce runoff quantity so on campus parking lots, plazas and sports fields will be converted into pervious surfaces to reduce runoff and recharge groundwater.

Bio-Swales: In the present condition, campus has open concrete channels, gutters and conveyances for stormwater drainage at some points. This study recommends these concrete channels to be converted into bio-swales which are vegetated drainage ways that provide both infiltration and filtration according to its type (Figure 5.95, 5.97, 5.99).



Figure 5.94. Present Condition



Figure 5.95. Future Condition



Figure 5.96. Present Condition



Figure 5.97. Future Condition



Figure 5.98. Present Condition



Figure 5.99. Future Condition

On the other hand swales on-contour act as retention or detention function. The first swale has a function of interception and retention of water and the second one intercept the overflow of water from the first swale. Roads and sidewalks can be a part of these structures (Phillips, 2005).

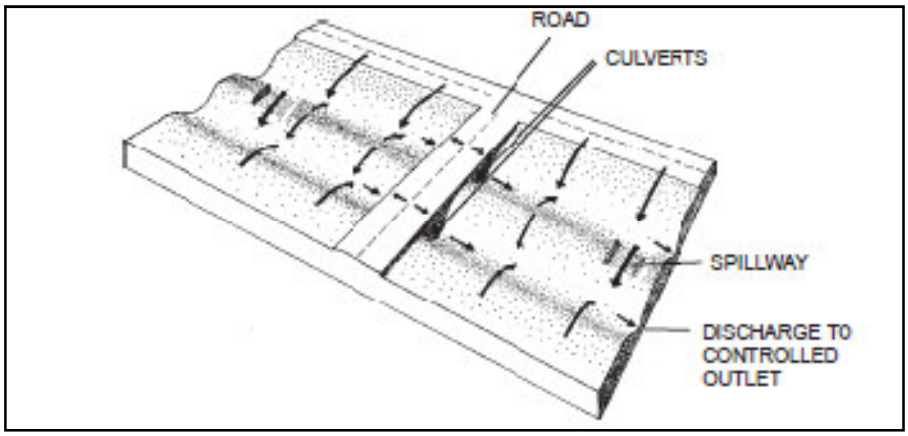


Figure 5.100. Swale on-contour
(Source: Phillips, 2005, p.7)

The steep sloped areas on campus will be applied with swale on-contour to provide surface runoff drainage (Figure 5.93).

Curb-cuts: Besides, curb-cuts are efficient drainage elements on roads and parking lots, they provide to direct surface runoff through a vegetative area or drainage channel, so on campus roads and parking lots, curb-cuts will be used as drainage element (Figure 5.102). Therefore, roads should be gently sloped on both of sides through pedestrian path to provide water flow.

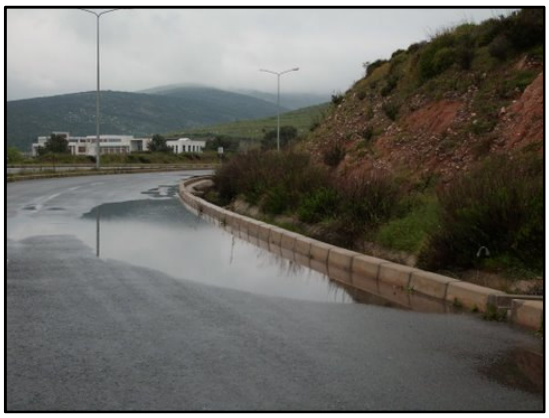


Figure 5.101. Present Condition



Figure 5.102. Future Condition

Catchment Basins: Some parts of campus which are almost flat or low sloped should be designed as basin areas like ponds, detention basins or bioretention areas. On IYTE Campus, there are five potential basin areas. The slope of these areas are proper for detention. Dry Ponds will be located in the Faculty of Architecture, close to the Faculty of Science, on the expansion area between the proposed buildings which are close to the Mechanical Engineering Building, close to Campus Green and the other one will be on the area nearby the channelized stream at south (Figure 5.103 to 5.107). Besides them, there will be filter strips at Faculty of Architecture and close to parking area which is across the sports building with a filtration function of runoff collected from stone and asphalt surfaces. These basin areas won't have permenant water. Generally, they are vegetative areas but they will become functional on heavy rainy days.



Figure 5.103. Proposed Detention Basin Area



Figure 5.104. Proposed Detention Basin Area



Figure 5.105. Proposed Detention Basin Area



Figure 5.106. Proposed Detention Basin Area



Figure 5.107. Proposed Detention Basin Area

Infiltration Planter Box: Buildings will be considered alone. All faculty buildings will have rainwater downspout system. The rainwater captured from roof will be drained with downspouts through planter boxes in front of the building (Figure 5.109). Planter boxes will infiltrate the runoff and reduce the runoff volume.



Figure 5.108. Present Condition



Figure 5.109. Future Condition

Rainwater Harvesting: Besides, barrels will be used as a small scale storage element in front of the buildings for roof drainage (Figure 5.111). Rainwater drained with downspouts from rooftops will be stored in barrels.



Figure 5.110. Present Condition



Figure 5.111. Future Condition

Greenroofs: On the other hand, new buildings should meet the LEED-ND design standards. Therefore, Green Roof applications will be a part of stormwater management scheme of campus (Figure 5.113).



Figure 5.112. Present Condition



Figure 5.113. Future Condition

Cisterns: On Campus, all the sports fields and some open spaces will provide a large scale underground storage, stormwater captured from surfaces will be directed through storage areas after filtration and stored water will be reuse for irrigation and water featured functions (Figure 5.114 and 5.115).



Figure 5.114. Proposed Underground Storage



Figure 5.115. Proposed Underground Storage

Water Efficient Landscape: Besides, the University administration should also develop a Landscape Master Plan with strategies that support Campus Stormwater Management Plan because Water-Efficient Landscape or High performance landscape has an important function to provide a sustainable system so an effective landscape design should be prepared and adopted campuswide with applying xeriscaping methods

to prevent water demand. Plants and trees have an absorbing and filtration role in the system so the vegetated areas and type of plant and trees play an important role and they increase the perviousness ratio so campus tree cover and planted areas should be increased. Campus has generally native trees which are olive and pistacia lentiscus (yabani sakız) and plants. They are water efficient and provide an opportunity for campus. Also, Landscape conversion from turf (grass) to natural vegetative cover is important for water demand and maintenance cost. Pest-management strategy which is provided with composting landscape waste on campus is necessary to prevent water pollution. Besides, mulching technique should be prefered for plants to prevent evapotranspiration because it helps to maintain moisture on soil so water consumption is declined.

Tree Well: Tree Wells are used on green streets as a stormwater harvesting technique. Surface runoff is drained from the pavement through the well and drained water is infiltrated through ground pipe system. On campus, the pedestrian paths both on the cafeteria road and on the other side of the hill will have tree well system (Figure 5.93).

Living Walls: Living walls are the supporter elements for sustainable systems as well as help to water management and have retention property. Each panel has cell so they can retain certain amount of water while providing good drainage. The faculty buildings' retaining walls will be turned into living wall (Figure 5.116 and 5.119).



Figure 5.116. Present Condition



Figure 5.117. Future Condition



Figure 5.118. Present Condition



Figure 5.119. Future Condition

Use of Air Conditioner Condensate: Air Conditioner Condensates are the alternative water resource instead of potable water use. This technique is essential for arid and semi-arid regions. IYTE Campus climate is proper for this, because summers are hot and have not any rainfall. All the academic buildings have air-conditioning system so this will become a potential for alternative water resource.

Green Parking: All parking lots will be turned into green parking. Firstly, the surface of the parking lot will be replaced with pervious pavement. Then, there will be bio-swale on it and curb-cuts will provide the flow of surface water through swale (Figure 5.121).



Figure 5.120. Present Condition



Figure 5.121. Future Condition

Green Street: Green Streets are the streets that use vegetated facilities to manage stormwater runoff at its source. The road nearby the cafeteria building will turned into green street. The concrete open channel will converted into swale and the across the swale, pedestrian way will have tree wells.



Figure 5.122. Present Condition



Figure 5.123. Future Condition

Curb Extension: Curb Extension are the vegetated drainage elements on streets and generally have two openings for drainage. They provide both the infiltration and filtration of stormwater. On campus, the road on the south side of library will be curb-extension (Figure 5.94).



Figure 5.124. Proposed Curb-Extension on Campus

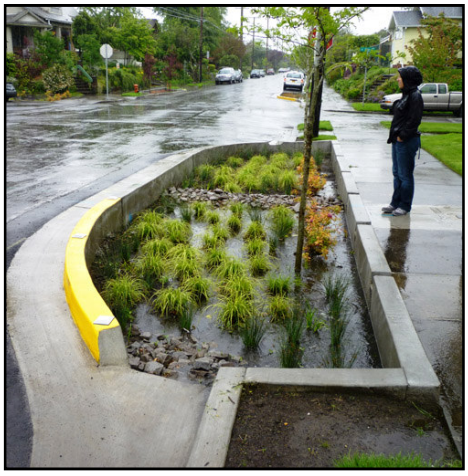


Figure 5.125. Future Condition

Stream Daylighting: The stream on the north basin that is near the Faculty of Science was burried to concrete channel but some part of this stream was completely burried ground so, this part will be daylighted (Figure 5.126).



Figure 5.126. Daylighted Part of the Stream

Greywater System: Greywater is collected with separate drain lines and system aims to filter the water to remove large particles and store until used for irrigation. Dormitory will be adopted and new project of student housing will be constructed with greywater system.

Demonstration Project Area: In addition to the retrofit green infrastructure BMP projects within the developed parts of the campus, the area between the Library and Mechanical Engineering Department is proposed to be a demonstration project area for application of Green Infrastructure Techniques for new constructions (Figure 5.93).

5.4. Summary

As a result, chapter five constitute the case part of the thesis. Firstly, Izmir Institute of Technology Campus is identified as a case area then campus site analysis are mentioned briefly for water management strategies and techniques to specify the existing conditions of the campus. Later, analysis are evaluated to expressed the problems or opportunities. According to the evaluation, the Best Management Practices are specified to determine which techniques are used and on which parts of the campus will be applied. Lastly, the techniques that are proposed for campus are expressed briefly in detail.

CHAPTER 6

CONCLUSION

The importance of environmental sustainability and protection of ecosystem issues has been taken into consideration in recent years because of environmental degredation. Ecosystem elements of soil, vegetation and water consitute a balance on nature. The increasing urbanization with high production and consumption has disturbed this natural balance. The role of natural hydrology in the system is important for regulating water suppliers and providing biological habitat and recreational opportunities. Current land use practices demonstrate the soil and vegetation disturbance, conventional drainage and stormwater management systems, contaminated stormwater runoff and inefficient water use. Therefore, to become aware of danger and struggle to be conscious against the environment is important. Water scarcity has been increased with unconscious applications and design strategies but water is a non-renewable entity and we need it as an essential of life. So, environmental responsibility should be adopted in the process of urban design at every scale and type of projects.

This study concentrates on sustainable water management through the use of green infrastructure techniques (natural drainage systems) to be more sustainable and it especially emphasizes the significance of water resources for dry and semi-dry climate regions. Here, the techniques and their functions are defined briefly. Besides, the existing conditions and the efficient results of sustainable stormwater infrastructure systems in university campuses in the world are specified. Then, to answer the Research Question of “How to guide future campus growth and development in a more sustainable manner with regards to water resources”, the case study has been conducted on IYTE Campus. The aim of the study is to provide the sustainability of water resources, conservation and improvement of water quality and quantity and cost effectiveness and lastly, enhance the ecological balance of campus. Therefore, identification of the existing stormwater infastructure condition of campus with analysis, then examination of the applicability of green infrastructure techniques on campus.

Green Infrastructure Systems are useful to become aware of the importance of water resources in campus design. The system is an range of products, technologies, and practices that use natural systems or engineered systems that mimic natural processes to enhance overall environmental quality and provide utility services. They help to develop natural stormwater drainage system in contrast to traditional systems with pipes, with an aim of holding the stormwater or rainwater to reuse and providing infiltration. Therefore, sustainable stormwater management requires the use of some structural and non-structural application techniques to reduce potable water consumption and protect water quality. These techniques can be exemplified as greenroofs, drainage elements like swale and planter boxes; basin elements like bioretention area, rain garden, pond, wetland, filterstrip, infiltration basin and filter trench, and lastly pervious paving. Additionally, Efficient Landscape Design or High Performance Landscape which uses native plants that are water efficient with use of proper irrigation method, supports these techniques with proper applications. All these techniques show that, the stormwater and rainwater are the potential alternative water resources to make use of. Its importance gets bigger with global warming because water is non-renewable entity and limited source in nature. However, these techniques provide cost-effective and environmentally improved solutions.

Around the world, most of the campus master plans and designs increasingly adopt sustainability approach to protect the vital sources and to prevent the environmental degradation. Protection of water resources become an important issue for universities in the world therefore most of them develop strategies to reduce the water use and keep it because the growth of the cities have affected the urban hydrology, so the world running out of potable water and groundwater level is lowered. On the other hand, sustainable campus design measures are developed in some countries around the world and most universities have taken these measurements as a guide in their campus design. However, there are some limitations that need to be taken into consideration for the techniques. Techniques should be used with caution since each site has unique features such as soil type, climatic conditions, geology, slope and vegetation. Also, these techniques require an interdisciplinary team work with the participants of Urban Designer, Landscape Architect, Geology Engineer and Civil Engineer because the process of analysis, design and application needs these fields' expertise.

As a case area, IYTE Campus is a non-urban site and has mostly natural landscape as a part of an ecosystem. This provides an opportunity to adopt Green

Infrastructure Techniques to existing system easily because these techniques aim to mimic nature in function to reduce the impact on ecological systems. Firstly, site analysis of Slope and Elevation, Geology and Soil, Watershed Context and Water Resources, Climate, Vegetative Cover, Campus Development Process and Infrastructure Scheme are conducted in a two category of natural and built-up systems to understand the existing condition of campus. Then, the problems and opportunities are identified with SWOT analysis. As a result, limitations of campus are low infiltration capacity soil type, less rainfall capacity climate type, disturbed site, less tree coverage, inadequate data, for example lack of soil, drainage, grading and water resources analysis of campus, lack of landscape and stormwater management plan of campus and lack of meteorological data, dependency of potable water. Therefore, mostly surface storage techniques are suggested because of the soil type but underground storage is efficient for longer usages so it can be adopted with manmade interventions. Forestration is proposed on sloped areas to prevent erosion, efficient landscape approach has been adopted to provide filtration and infiltration and reduce water consumption. Sustainable Water Resource Management strategies are developed according to LEED-ND Rating System measures which are commonly used in campus expansion projects to be more sustainable. A growing number of the University Campus Designs are applied according to LEED-ND green design standards in U.S.A.

Best Management Practice techniques are developed in an interdisciplinary study. The use of these techniques requires geological and hydrological analysis; rainfall data and runoff calculations for hydrological modeling, digital elevation modeling and BMP sizing and capacity calculations. Therefore, in this research, a conceptual Stormwater Management Scheme for IYTE Campus has been developed with a point of view of urban design. The locations of the BMPs are identified according to the analysis. Suggested BMPs are for campus wide and aim to capture stormwater and rainwater both on surface and underground and prevent to drain directly to stream. A Demonstration Project Area is defined that includes new constructions of Faculty Buildings, so BMPs will solve the runoff problem at the source and provide rainwater infiltration with mimic the natural process. They will also prevent water pollution because they have a function of filtration before water enters the system and will constitute natural and sustainable drainage system on IYTE Campus.

This study is to promote IYTE Campus to be a role model for other university campuses and cities both in Izmir and Turkey. The vision of protecting the campus site

character and environmental quality, producing green and environmentally sustainable structures with expression of campus as an incubator should be adopted by IYTE Administration as environmental assets play an important role in the development process. Therefore, the proposed Stormwater Management Scheme constitutes the initial step to guide further development of Campus Stormwater Management Plan. Also, this study will play an important part of a process of becoming a “Green Campus” where the projects of wind tribunes, use of waste water recycle and drip irrigation system that are recently put into practice.

Further research suggestions consist of a comprehensive process of conducting hydro-geological analysis, and producing the data of meteorology by establishing a local meteorological unit on campus, as well as hydrology that includes runoff calculations and modeling, hydrological modeling and BMP sizing and capacity calculations. Also, the use of computer based programs like Arc-Gis Hydro for analysis and Digital Elevation Modeling (DEM) for determination of watershed hydrology will provide to get the best results. As a result, this process needs an interdisciplinary study to give the effective results for campus.

REFERENCES

Ağan, H., (2000). Design Criteria of-In Campus Sport Facilities with Reference to World University Sports Competitions, A Case Study in IZTECH Campus, Master Thesis. İzmir Institute of Technology.

Alshuwaikhat, M. H. , Abubakar, I. , (2007). An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices.

Al-Joyyusi, O., R., (2003).Greywater Reuse:Towards Sustainable Water Management. Desalination, 156,181-192

Andropogon Associates, Cahill Associates, The Rose Group, (2004). University of North Carolina at Chapel Hill Stormwater Management Plan Final Report. Retrieved from http://ehs.unc.edu/environmental/stormwater/docs/final_report2004.pdf

Annis Water Resources Institute, Grand Valley State University, (2002). Stormwater Educational Handbook. Retrieved from http://scholarworks.gvsu.edu/cgi/viewcontent.cgi?article=1005&context=egmo&seiredir=1#search="Annis+Water+Resources+Institute+Grand+Valley+State+University, (2002).Stormwater+Educational+Handbook."

Artfulrainwaterdesign, 20.12.2010 http://www.artfulrainwaterdesign.net/photos/show/193/

Arizona, 10.05.2011 http://cfp2.web.arizona.edu/files/UA%20Surface%20Water%20Master%20Implementation%20Plan-FINAL-2-13-09-optimized.pdf

Asla-1, 15.07.2010 http://www.asla.org/awards/2006/06winners/341.html

Asla-2, 10.03.2010 http://www.asla.org/sustainablelandscapes/sonoran.html

Baba, A. et al., (2010). İzmir Yüksek Teknoloji Kampüs Alanı İçerisindeki Yüzeysel Suların Sürdürülebilirliği (Jeolojik-Jeofizik Çalışmalar). Civil Engineering Department, Izmir Institute of Technology.

Belan, G., Otto, B., (2004). Catching the Rain.A Great Lake Resource Guide For Natural Stormwater Management. Retrieved from http://act.americanrivers.org/site/DocServer/CatchingTheRain.pdf

Bell S. and Morse S., (1999). Sustainability indicators: measuring the immeasurable. London: Earthscan Publications.

Benson and Roe, (2000). A Systems approach to landscape.

Breeam, 7.11.2009
http://www.breeam.org/index.jsp

Brgov, 03.03.2010
http:// brgov.com/dept/planning/pdf/Gallo.pdf

Britannica, 05.03.2011
http://www.britannica.com/EBchecked/topic/372651/mediterranean-climate

Buildgreen, 2009, 13/01/2010
http://buildgreen.ufl.edu/LID_fact_sheets.htm

Buyutec, 02.02.2011
http://www.buyutec.net/p-izmir-haritasi-3-26192.html

Cabmphondbooks, 10.08.2009
http://www.cabmphondbooks.com/development.asp

California Stormwater Quality Association, (2003). California Stormwater BMP Handbook-New Development and Redevelopment Handbook. Retrieved from http://www.cabmphondbooks.com/development.asp

Campus Planning Committee, (2000). Sustainable Development Plan-University of Oregon. (Updated September 2005). Retrieved from http://sustainability.uoregon.edu/content/reports-resources

Carboun, 8.05.2011
http://www.carboun.com/sustainable-development/sustainable-design/kaust-a-sustainable-campus-by-the-red-sea/

Chocat, B., Ashley, R., Marsalek, J., Matos, M.R., Rauch W., Schilling, W., Urbonas, B., (2007). Toward the Sustainable Management of Urban Stormwater. Indoor and Built Environment. 16, 3:273-285.

Ciegis, R., Gineitiene, D., (2006). The Role of Universities in Promoting Sustainability. ISSN 1392-2785 Engineering Economics. No:3 (48). Retrieved from http://www.ktu.lt/lt/mokslas/zurnalai/inzeko/48/1392-2758-2006-3-48-56.pdf

Cole, L., (2003). "Assessing Sustainability on Canadian University Campuses: Development of a Campus Sustainability Assessment Framework, Canada: Royal Roads University.

Cole, L., (2003). Campus Sustainability Assessment Framework.86 Pages. Retrieved from www0.umoncton.ca/symbiose/files/CSAF.pdf

Department of Planning and Local Government, (2010). Water Sensitive Urban Design Technical Manual,Greater Adelaide Region. Retrieved from http://www.planning.sa.gov.au/go/wsud

Dmi, 10.05.2011
http://www.dmi.gov.tr/veridegerlendirme/aylik-normal-yagis-dagilimi.a

Echols, S. and Pennypacker, E., (2008). From Stormwater Management to Artful Rainwater Design Landscape Journal 27:2-08 p. 268-290.

Europa, 7.03.2010
http://ec.europa.eu/environment/emas/about/summary_en.htm

Ecolandscapegroup, 10.05.2011
http://www.ecolandscapegroup.com/garden-biochar-and-rain-gardens/

Elfland, C., Myers. S., Brown, T. and Hoyt, S., (2008). Green Infrastructure at the Campus and Watershed Scale at the University of North Carolina at Chapel Hill. Ehs.unc.edu/ehs/docs/wefsus2008.ppt

Environmental Building News, (2010). Alternative Water Sources: Supply-Side Solutions for Green Buildings. Retrieved from http://www.buildinggreen.com/auth/article.cfm/2008/4/29/Alternative-Water-Sources-Supply-Side-Solutions-for-Green-Buildings/

Environment-agency, 05.06.2010
http://www.environment-agency.gov.uk/business/sectors/36998.aspx

Environmental Stewardship Committee, (2002). Stanford University. Guidelines for Sustainable Building. Retrieved from http://sustainable.stanford.edu/sites/sem.stanford.edu/files/documents/Stanford_sustainable_guidelines.pdf

Epa, 07.08.2009
www.epa.gov/npdes/webcasts/certificate/gi_siteplanning.pdf

Faha, M., King, J., (2009). Asla Leed Ap.Greenworks Landscape Architecture.Green Streets-Green Infrastructure. Retrieved from www.oeconline.org/our-work/rivers/rivers-files/green-streets-jason-king

Fmlink, 07.09.2010
http://www.fmlink.com/ProfResources/HowTo/article.cgi?BOMI%20International:howto040110.html

France, R., (2002). Handbook of Water Sensitive Planning and Design. Lewis Publishers. A CRC Press Company.

Georgiastormwater, 10.09.2010
http://www.georgiastormwater.com/

Googleearth, 2005. 10.04.2011
www.googleearth.com

Gupta, N., Ashok, S., (2007). Design of Water Conservation System Through Rainwater Harvesting: An Excel Sheet Approach. Retrieved from http://www.inepo.com/english/up/Files_resim/LearniumEnvProject.pdf

Hoban, A., and Wong, T.H.F., (2006). "WSUD Resilience to Climate Change". 1st International Hydropolis Conference, Pert WA, October, 2006. Retrived from http://waterbydesign.com.au/wpcontent/uploads/drupals/Water%20by%20Design%20Course%20Brochure.pdf

Horin, E. B.,(2007).Rainwater as a Resource.A Report on Three Sites Demonstrating Sustainable Stormwater Management. Retrieved from http://www.treepeople.org/rainwater-resource

Hydrotechusa-1, 10/12/2010
http://www.hydrotechusa.com/intensive-lawn.html

Hydrotechusa-2, 10/12/2010
http://www.hydrotechusa.com/garden-roof.htm

Iie, 8.05.2011
http://www.iie.org/en/Programs/KAUST

Kaust, , 8.05.2011
http://inauguration.kaust.edu.sa/university/sustainable-development.aspx

Infolink,, 02/12/2010
http://www.infolink.com.au/c/Atlantis-Water-Management/Atlantis-Water-Management-infiltration-tank-solutions-n902668

Invisible Structures, 15.11.2009
http://www.invisiblestructures.com

Kaust, 8.05.2011
http://www.kaust.edu.sa/about/sustainable/water.html

Kinkade H.,L., (2007). Design for Water:Rainwater Harvesting, Stormwater Catchment and Alternate Water Reuse. Retrieved from http://library.iyte.edu.tr//

Ladstudios, 15.05.2011
http://www.ladstudios.com/LADsites/Sustainability/Strategies/Strategies_TreeWell.shtml

Lukman,R., Tiwary, A. and Azapagic,A., (2009). Towards greening a university campus: The case of the University of Maribor, Slovenia. Resources, Conservation and Recycling, 53 , 639–644.

Marbleport, 12.03.2011
http://www.marbleport.com/guncelhaberler/universiteler-yesil-kampusler-kuruyor-1532.html

Mat, S., Sopian, K., Mokhtar, M., Ali, B., Hashim, H., S., Rashid, A., K., A., ain, M., F., M. and Abdullah, N., G, (2009). Managing Sustainable Campus in Malaysia – Organisational Approach and Measures.European Journal of Social Sciences – Vol. 8, N0:2.

Melbourne Water Corporation, (1999). Urban Stormwater Best Practice Environmental Management Guidelines

Metrocouncil, 13.12.2010
http://www.metrocouncil.org/environment/Water/BMP/CH3_STDetDrySwale.pdf

Mikulik, J., Babina, M., (2009). The Role of Universities in Environmental Management.Polish J. of Environ.Stud.Vol.18,No:4, 527-531.

MIT, 10.03.2010
http://web.mit.edu/facilities/about/features/StataBioswale10_10_07.pdf

MIT Stata Center-A Benchmark for Green Standards, (2008). Retrieved from http://skanska-sustainability-case-studies.com/pdfs/23/23_MIT_v001.pdf

Neuman, D. J. , (2003). Building Type Basics for College and University facilities. John Wiley and Sons Ltd, illustrated ed Edition , 320 pages, Hardback.

Novotny, V., Ahern, J., Brown, P., (2010). Water Centric Sustainable Communities. Planning, Retrofitting and Building the Next Urban Environment. John Wiley & Sons, Inc., Hoboken, New Jersey.

Oeconline, 19.11.2009
http://www.oeconline.org/our-work/rivers/rivers-files/green-streets-jason-king

Oxford English Dictionary, (2009). Oxford University Press. Retrieved from http://library.iyte.edu.tr/index.php/lang-tr/veritabanlari.html.

Ozyegin, 10.03.2011
http://www.ozyegin.edu.tr/MEDYA/OzUden-Videolar/Cekmekoy-Kampusu-3D-Videosu?lang=tr-TR

Padmanabhan, A., (2009).Stormwater Evaluation and Site Assessment — A Multidisciplinary Approach for Stormwater Best Management Practices (BMPs). Master Thesis, Kansas: Department of Landscape Architecture / Regional and Community Planning College of Architecture, Planning and Design Kansas State University,Kansas

PDX-1, 12.09.2010
http: // www.pdx.edu / sustainability / water

PDX-2, 12.09.2010
http://www.pdx.edu/sites/www.pdx.edu.sustainability/files/media_assets/sus_epler_case_study.pdf

Philips, A. A., (2005). City of Tuscon Water Harvesting Guidance Manual.

Pisciotti, L., (1994). Izmir Institute of Technology Feasibility Report, IYTE, Izmir

Portland Bureau of Environmental Services, (2010). Portland Green Street Program.City of Portland,Oregon. Retrieved from http://www.portlandonline.com/bes/index.cfm?c=44407

Portlandonline, 19.11.2009 http://www.portlandonline.com/shared/cfm/image.cfm?id=153974

Prakopcyk, R. and Staudt, R., ASLA, (2008). Sustainable Site Design At Georgia Tech. Retrieved from http://www.asla.org/ppn/Article

Ried, R., (2008). Using Leed asa resource for Campus Sustainability Planning: A White Paper. University of California Berkeley.

Riversides, 10.11.2010 http://www.riversides.org/rainguide/riversides_hgr.php?cat=2R&page=39&subpage=92&subpage2=44

Sabanciuniv, 10.03.2011 http://www.sabanciuniv.edu/sudergi/pdf/mayis_dergi.pdf

SanFrancisco Planning and Urban Research Association, (2006). Integrated Stormwater Management, Adding an ecological component to San Francisco's streets. Retrieved from http://www.spur.org/publications/library/report/Abs_integratedstormwatermanagement_110706

Seymour, R. M., (2005). Capturing Rainwater to Replace Irrigation Water for Landscapes:Rain Harvesting and Rain Garden.Proceedings of the 2005 Georgia Water Resources Conference at the University of Georgia.

Sorvig, K., (2010). Drowning in the Desert: A Zero-budget at the University of Arizona harvests water from the adjacent building, Landscape Architecture, Vol. 100 No:1, p.26-37.

Gatech, 15.07.2010 http://www.space.gatech.edu/landscape plan

Stephen E. Epler Hall-Portland State University, (2010). Retrieved from http://www.pdx.edu/sites/www.pdx.edu.sustainability/files/media_assets/sus_epler_case_study.pdf

Stewart, C., (2005). Campus Sustainability Assessment Progress Report. Retrieved from http://geog.utm.utoronto.ca/conway/ecofootprint/doc/CSAreport2005.pdf

Stormwater Center, 10.11.2010
http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Open%20Channel%20Practice/Grassed%20Channel.htm

Stormwater-harvesting, 02/12/2010
http://www.stormwater-harvesting.com.au/Re_Use_Tank.pdf

Stormwaterpartners, 07.09.2010
http://www.stormwaterpartners.com/facilities/catchbasin.html

Sustainability at Georgia Tech Office of Environmental Stewardship, (2007). Stormwater Managemet.Georgia Institute of Technology. Retrieved from http://www.stewardship.gatech.edu/stormwater

Tayfur, G., (2010). İzmir Yüksek Teknoloji Enstitüsü Kampus Alanı Yeraltı ve Yerüstü Su Kaynakları Potansiyelinin Araştırılması. (Bap Projesi Raporu). Civil Engineering Department, Izmir Institute of Technology

Tilley, S., (2003). Natural Approaches to Stormwater Management.Low Impact Development in Puget Sound. Retrieved from http://www.epa.gov/watertrain/smarthgrowth/resources/pdf/lid_natural_approaches.pdf

The South East Queensland Healthy Waterways Partnership, (2009). Water by Design Program. Retrieved from http://waterbydesign.com.au/wpcontent/uploads/drupals/Water%20by%20Design%20Course%20Brochure.pdf

Toronto City Planning, (2007). Design Guidelines for Greening Surface Parking Lots. Retrieved from http://www.toronto.ca/planning/urbdesign/pdf/greening_parking_lots_dg_update_16nov07.pdf

Tredyffrin, 10.04.2011
www.tredyffrin.org/pdf/.../CH2%20-%20BMP6%20Planter%20Box.pdf

Tuna,G., (2006). Assesing Green Design Approach to Develop a Conceptual Model for Landscape Planning in University Campuses, Master Thesis. İstanbul Technical University.

Turner, C., (2005). A First Year Evaluation of the Energy and Water Conservation of Epler Hall: Direct and Societal Savings. Portland State University.

UNC Sustainability Office, (2009). Campus Sustainability Report. Retrieved from http://sustainability.unc.edu/LinkClick.aspx?fileticket=0HfU90GhB_Q%3D&tabid=423

UNC-1, 10.08.2009
http://ehs.unc.edu/environmental/stormwater/docs/final_report2004.pdf

UNC-2, 10.08.2009
http:// Ehs.unc.edu/ehs/docs/wefsus2008.ppt

UNC-3, 07.09.2010
http://www.fpc.unc.edu/portals/FPnC/Documents/Plans/MasterPlan/UNC-Update061907.pdf

University of Florida, (2008). Program for Resource Efficient Communities.Low Impact Development Fact Sheets. Retrieved from http://buildgreen.ufl.edu/LID_fact_sheets.htm

University of Wisconsin Milwaukee, (2006).UWM Final Report. UWM as a zero disharge zone:Stormwater Master Plan For UWM Campus.

USGBC, The LEED 2009 for Neighborhood Development Rating System, (2009).Washington. Retrieved from http://www.usgbc.org/

USGBC, 04.11.2009.
http://www.usgbc.org/

Waterbydesign, 08.08.2010
http://waterbydesign.com.au/wpcontent/uploads/drupals/Water%20by%20Design%20Course%20Brochure.pdf

Werf, 10.11.2010
http://www.werf.org/livablecommunities/studies_truckee_nv.htm

Wikipedia, 05.03.2011
http://en.wikipedia.org/wiki/Climate_of_the_United_States

Velazquez , L. , Munguia,N., Platt, A., Taddei,J., (2006). Sustainable university: what can be the matter? Journal of Cleaner Production,14, 810-819.

Villanova Urban Stormwater Partnership, (2001). Villonova Stormwater Best Management Practice Demonstration Park. Retrieved from http://www3.villanova.edu/vusp/Outreach/Pdf/BMP_Park-App_B.pdf

Villanova-1, 10.03.2010
http://www3.villanova.edu/vusp/bmp_research/bio_traffic

Villanova-2, 10.03.2010
www3.villanova.edu/VUSP/OLD/VUSP_QAQC_July-2005.pdf

Virginia, 10.10.2010
http://ehs.virginia.edu/ehs/ehs.stormwater/stormwater.html

Yazar, K. H., (2006). ”Sürdürülebilir Kentsel Gelişme Çerçevesinde Orta Ölçekli Kentlere Dönük Kent Planlama Yöntem Önerisi”.Doctoral Dissertation, Ankara: Ankara Üniversitesi.

Yesilbinadergisi, 12.03.2011
http://www.yesilbinadergisi.com/?pid=23469

Yourhome, 02.05.2011
http://www.yourhome.gov.au/technical/fs78.html

APPENDIX A

DETAIL OF PROPOSED BMPS FOR IYTE CAMPUS



Figure A.1. Best Management Practices for IYTE Campus Faculty of Architecture

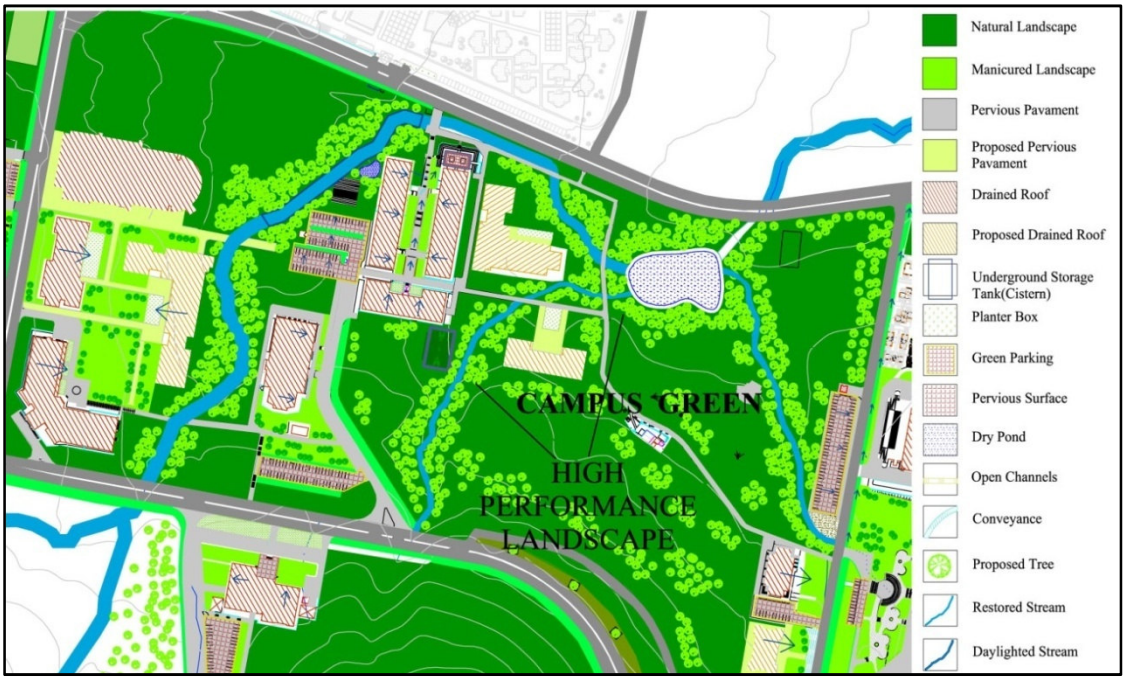


Figure A.2. Best Management Practices for the Area of Faculty of Science including Campus Green

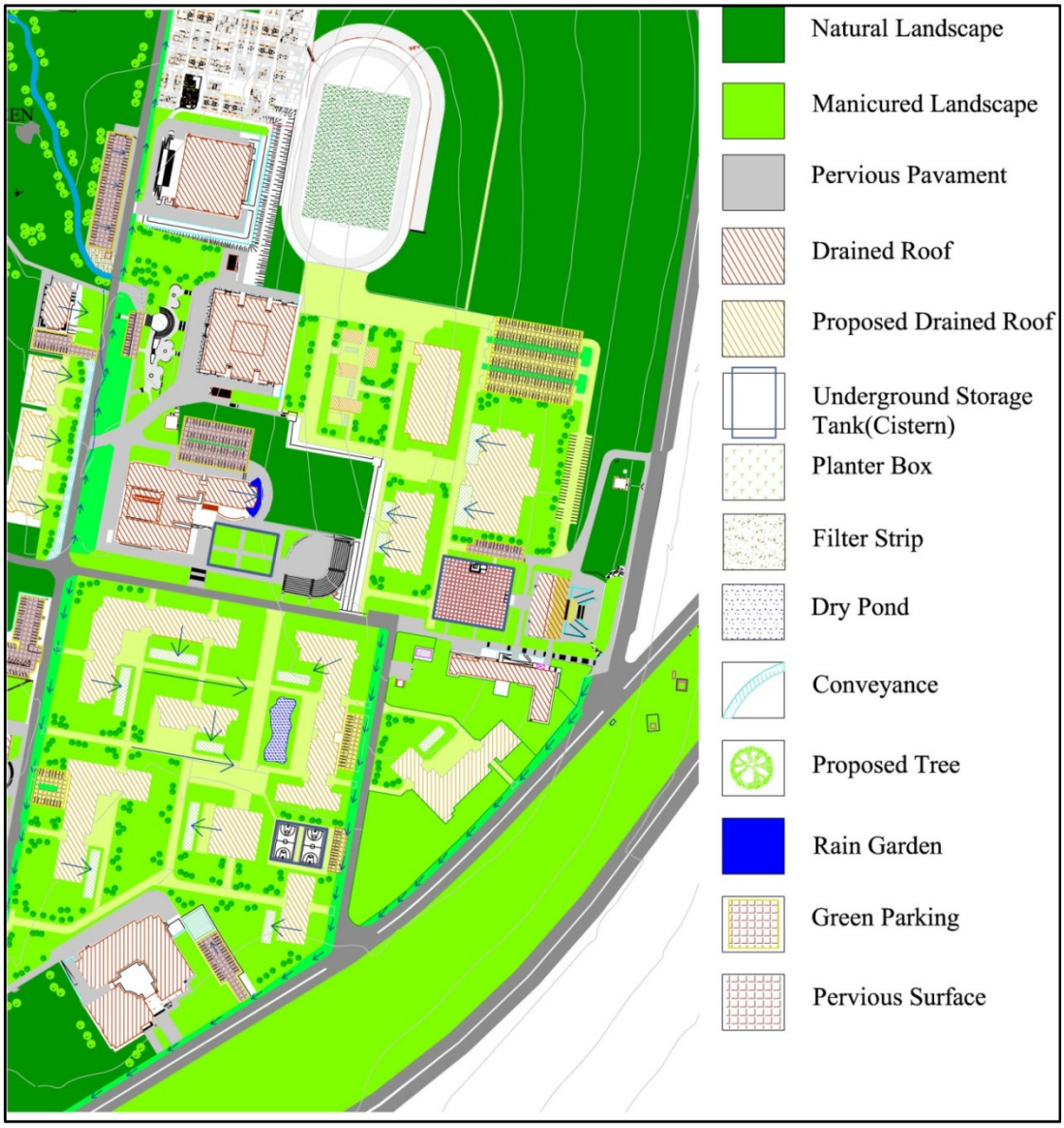


Figure A.3. Best Management Practices for the Area of Sport, Computer Engineering and Library Building



Figure A.4. Best Management Practices for the Area of Laboratories and Technopark

APPENDIX B

LEED-ND (2009) RATING SYSTEM

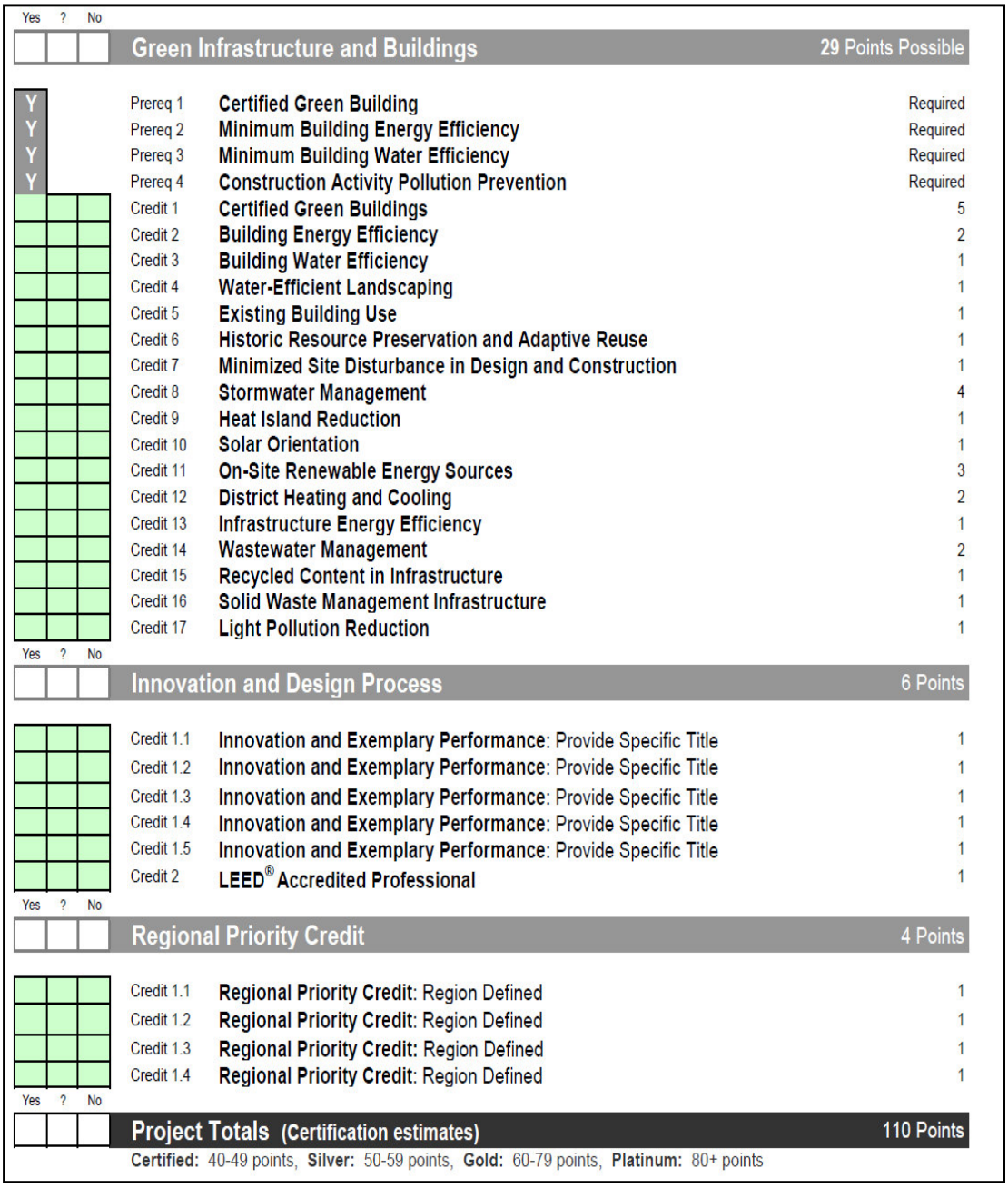
LEED 2009 for Neighborhood Development
Project Scorecard

Project Name:

Yes	?	No			
			Smart Location and Linkage		27 Points Possible
Y			Prereq 1	Smart Location	Required
Y			Prereq 2	Imperiled Species and Ecological Communities	Required
Y			Prereq 3	Wetland and Water Body Conservation	Required
Y			Prereq 4	Agricultural Land Conservation	Required
Y			Prereq 5	Floodplain Avoidance	Required
			Credit 1	Preferred Locations	10
			Credit 2	Brownfield Redevelopment	2
			Credit 3	Locations with Reduced Automobile Dependence	7
			Credit 4	Bicycle Network and Storage	1
			Credit 5	Housing and Jobs Proximity	3
			Credit 6	Steep Slope Protection	1
			Credit 7	Site Design for Habitat or Wetland and Water Body Conservation	1
			Credit 8	Restoration of Habitat or Wetlands and Water Bodies	1
			Credit 9	Long-Term Conservation Management of Habitat or Wetlands and Water Bodies	1

Yes	?	No			
			Neighborhood Pattern and Design		44 Points Possible
Y			Prereq 1	Walkable Streets	Required
Y			Prereq 2	Compact Development	Required
Y			Prereq 3	Connected and Open Community	Required
			Credit 1	Walkable Streets	12
			Credit 2	Compact Development	6
			Credit 3	Mixed-Use Neighborhood Centers	4
			Credit 4	Mixed-Income Diverse Communities	7
			Credit 5	Reduced Parking Footprint	1
			Credit 6	Street Network	2
			Credit 7	Transit Facilities	1
			Credit 8	Transportation Demand Management	2
			Credit 9	Access to Civic and Public Spaces	1
			Credit 10	Access to Recreation Facilities	1
			Credit 11	Visitability and Universal Design	1
			Credit 12	Community Outreach and Involvement	2
			Credit 13	Local Food Production	1
			Credit 14	Tree-Lined and Shaded Streets	2
			Credit 15	Neighborhood Schools	1

Figure B.1. LEED-Neighborhood Development (2009)
(Source: USGBC, 2010)



Yes	?	No			
			Green Infrastructure and Buildings		29 Points Possible
Y			Prereq 1	**Certified Green Building**	Required
Y			Prereq 2	**Minimum Building Energy Efficiency**	Required
Y			Prereq 3	**Minimum Building Water Efficiency**	Required
Y			Prereq 4	**Construction Activity Pollution Prevention**	Required
			Credit 1	**Certified Green Buildings**	5
			Credit 2	**Building Energy Efficiency**	2
			Credit 3	**Building Water Efficiency**	1
			Credit 4	**Water-Efficient Landscaping**	1
			Credit 5	**Existing Building Use**	1
			Credit 6	**Historic Resource Preservation and Adaptive Reuse**	1
			Credit 7	**Minimized Site Disturbance in Design and Construction**	1
			Credit 8	**Stormwater Management**	4
			Credit 9	**Heat Island Reduction**	1
			Credit 10	**Solar Orientation**	1
			Credit 11	**On-Site Renewable Energy Sources**	3
			Credit 12	**District Heating and Cooling**	2
			Credit 13	**Infrastructure Energy Efficiency**	1
			Credit 14	**Wastewater Management**	2
			Credit 15	**Recycled Content in Infrastructure**	1
			Credit 16	**Solid Waste Management Infrastructure**	1
			Credit 17	**Light Pollution Reduction**	1
Yes	?	No			
			Innovation and Design Process		6 Points
			Credit 1.1	**Innovation and Exemplary Performance**: Provide Specific Title	1
			Credit 1.2	**Innovation and Exemplary Performance**: Provide Specific Title	1
			Credit 1.3	**Innovation and Exemplary Performance**: Provide Specific Title	1
			Credit 1.4	**Innovation and Exemplary Performance**: Provide Specific Title	1
			Credit 1.5	**Innovation and Exemplary Performance**: Provide Specific Title	1
			Credit 2	**LEED® Accredited Professional**	1
Yes	?	No			
			Regional Priority Credit		4 Points
			Credit 1.1	**Regional Priority Credit**: Region Defined	1
			Credit 1.2	**Regional Priority Credit**: Region Defined	1
			Credit 1.3	**Regional Priority Credit**: Region Defined	1
			Credit 1.4	**Regional Priority Credit**: Region Defined	1
Yes	?	No			
			Project Totals (Certification estimates)		110 Points

Certified: 40-49 points, **Silver:** 50-59 points, **Gold:** 60-79 points, **Platinum:** 80+ points

Figure B.2. LEED-Neighborhood Development (2009)
(Source: USGBC, 2010)