低衝擊開發的理念,案例 及對排水防洪的效益評估

The Principles of Low Impact Development (LID), Case Studies and Its Effectiveness on the Drainage and Flood Mitigation

Keh-Han Wang
(王克漢)

Professor and Director of Civil Engineering Graduate Program
Dept. of Civil and Environmental Engineering, University of Houston
Houston, TX, USA.

Outline

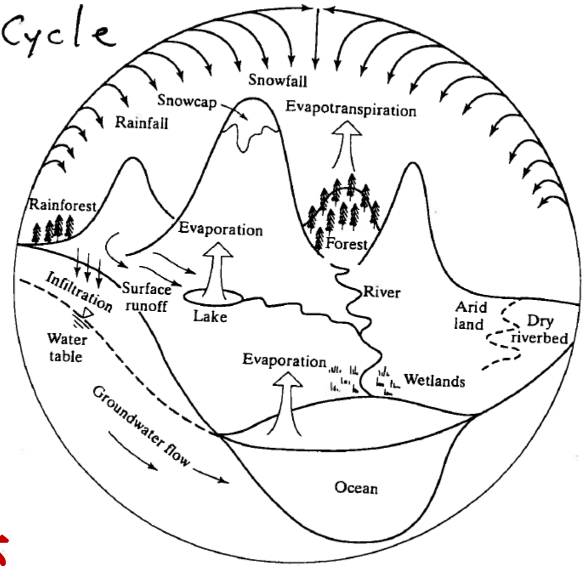
- Introduction （緒論-低衝擊開發及其理念）
- Conventional Development Approach （傳統開發方法）
- Drainage Analysis （排水分析）

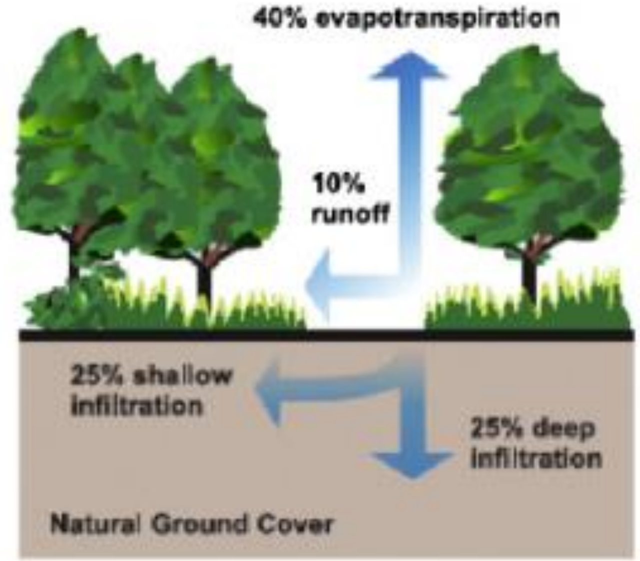
Hydrology and Hydraulics calculation （水文及水理演算）

- LID Approach（低衝擊開發方法）
- Case Studies （案例）
- LID Decision Support System（低衝擊開發的決策系統）
- LID Benefits （低衝擊開發所產生的利益）
- Conclusions （結論）

Introduction （緒論）

Hydrological Cycle

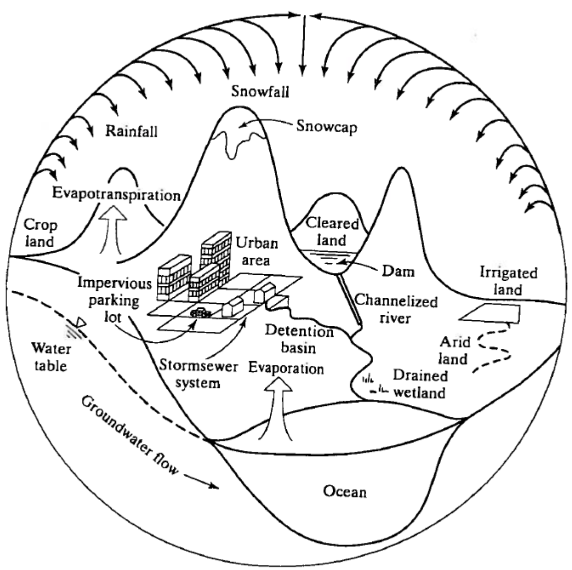


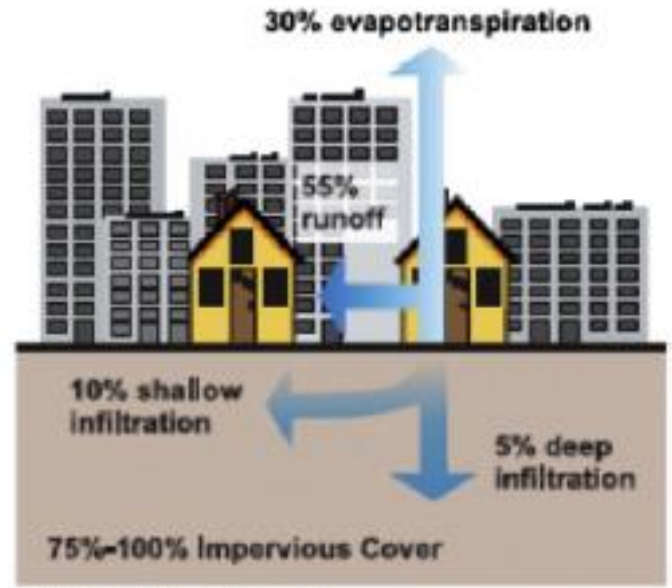


水文循環系統

Hydrological cycle of a natural environment

(a) pre-development





Hydrological cycle of a developed environment

(b) post-development

www.sciencedirect.com

低衝擊開發- Low Impact Development （LID）

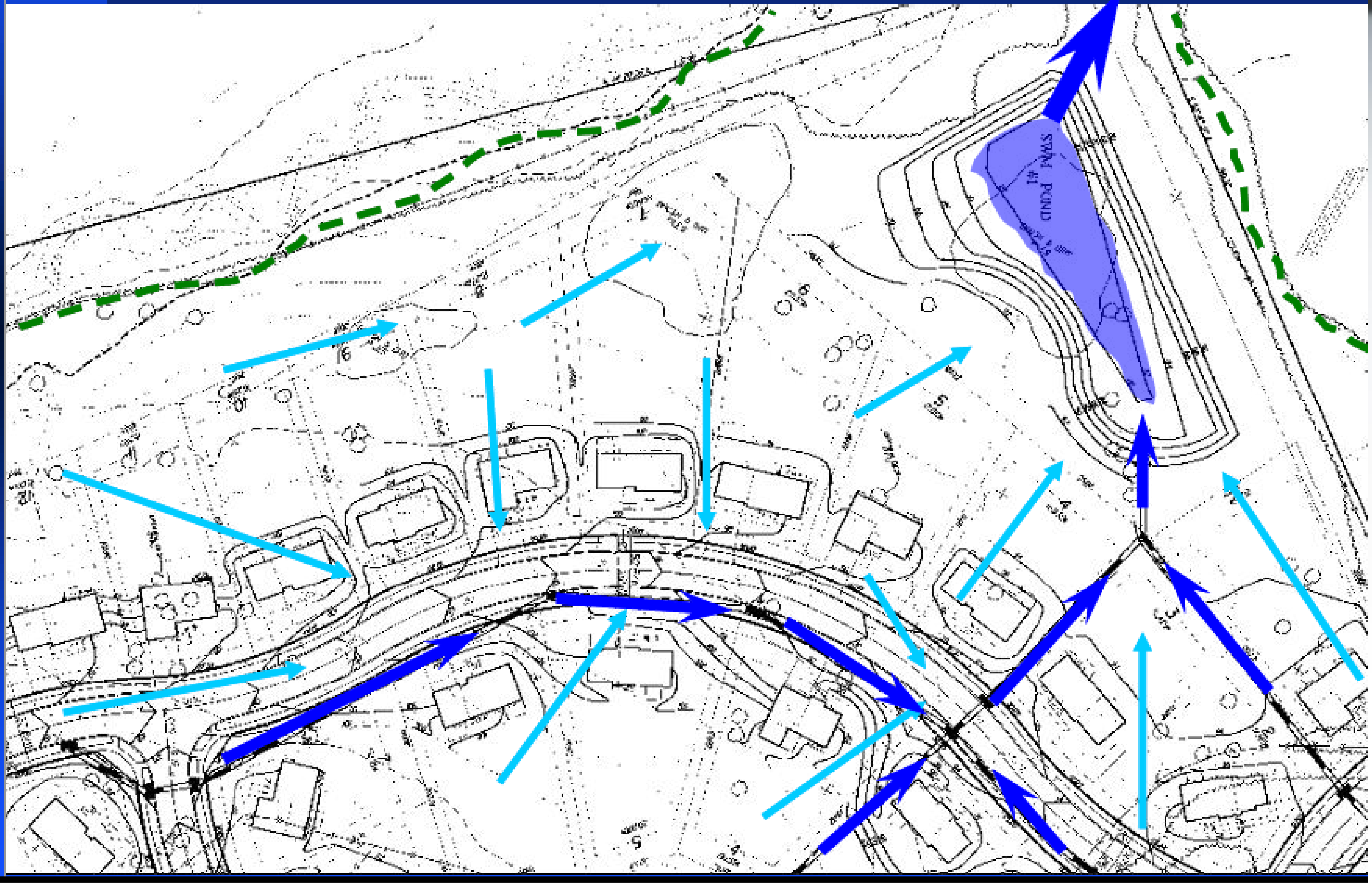
- Low Impact Development (LID) is a comprehensive land planning and engineering design approach with the goal of maintaining, as the minimum, the pre-development hydrologic regime in a watershed without solely using conventional development and detention basin techniques to satisfy drainage and flood mitigation requirements.

- 低衝擊開發 是一種不用傳統開發方式及盡量為了保持未開發前的水文及排水狀態而發展 成的一種綜合性的 土地開發和工程設計的方法

LID理念

- Conserve natural resources that provide valuable natural functions associated with controlling and filtering storm water and lead to pollution prevention (SW3P-Storm Water Pollution Prevention Plan requirement). （保存自然資源-管制及過濾雨水並可進一步防止水污染）
- Minimize & disconnect impervious surfaces (減少及分離不透水面）
- Direct runoff to natural and landscaped areas conducive to infiltration. （直接涇流入滲到自然景觀區域）
- Use distributed small-scale controls to mimic the site’s pre-project hydrology. （利用分散及小區域的雨水管制達到類似未開發前的水文狀態）
- 和自然界共同管理及使用土地

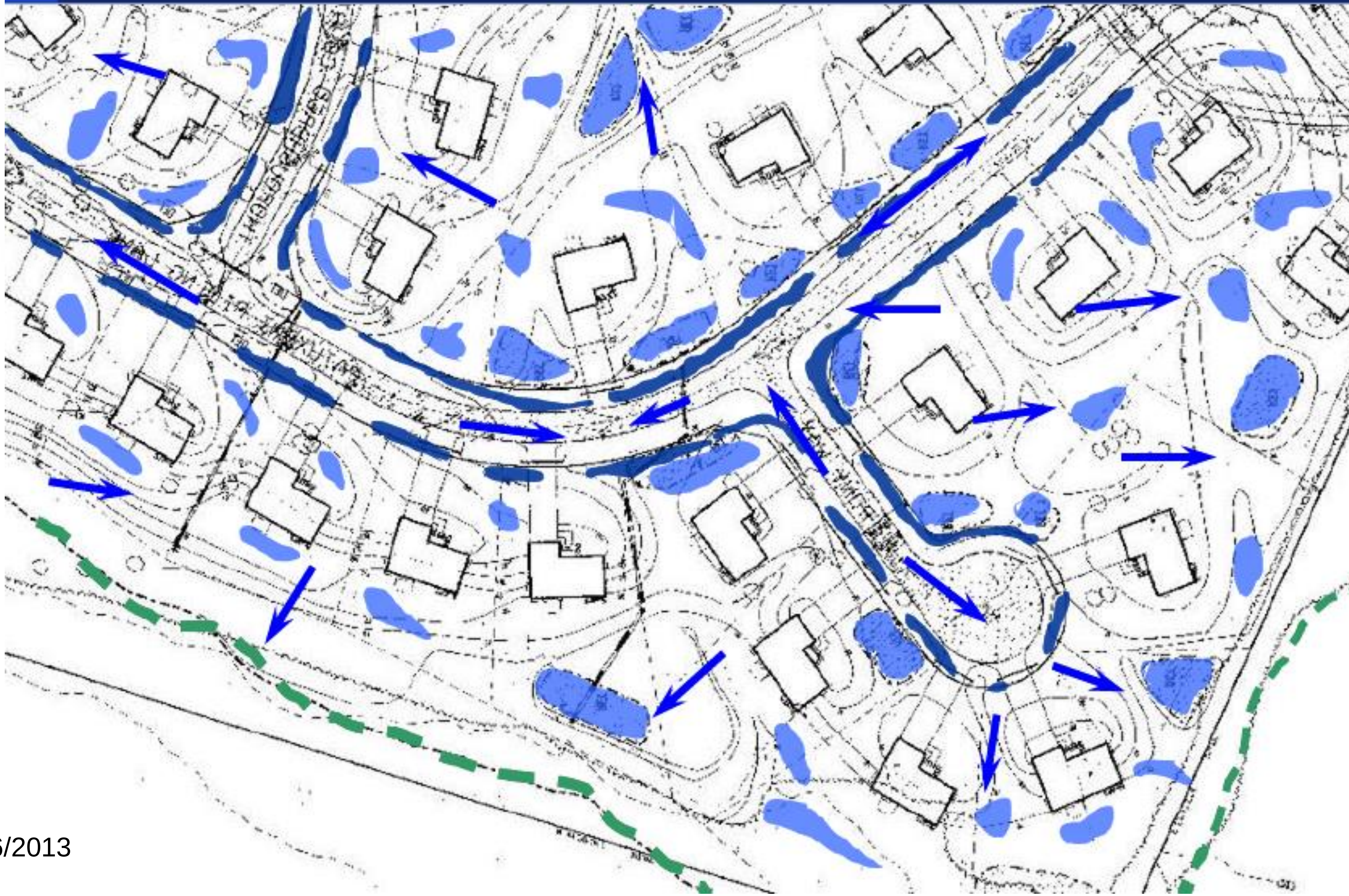
Conventional Pipe and Pond Centralized Control



Stormwater Management Pond

HOUSTON

LID Uniform Distribution of Micro Control



LID Site Planning Concepts （LID 用於開發區設計的概念）

The fundamental concepts that define the essence of low impact development technology must be integrated into the site planning process to achieve a successful and workable plan. These concepts are so simple that they tend to be overlooked, but their importance cannot be overemphasized. The steps to achieve LID include first minimizing the hydrologic impacts created by the site development through site design, and then providing controls to mitigate or restore the unavoidable disturbances to the hydrologic regime.

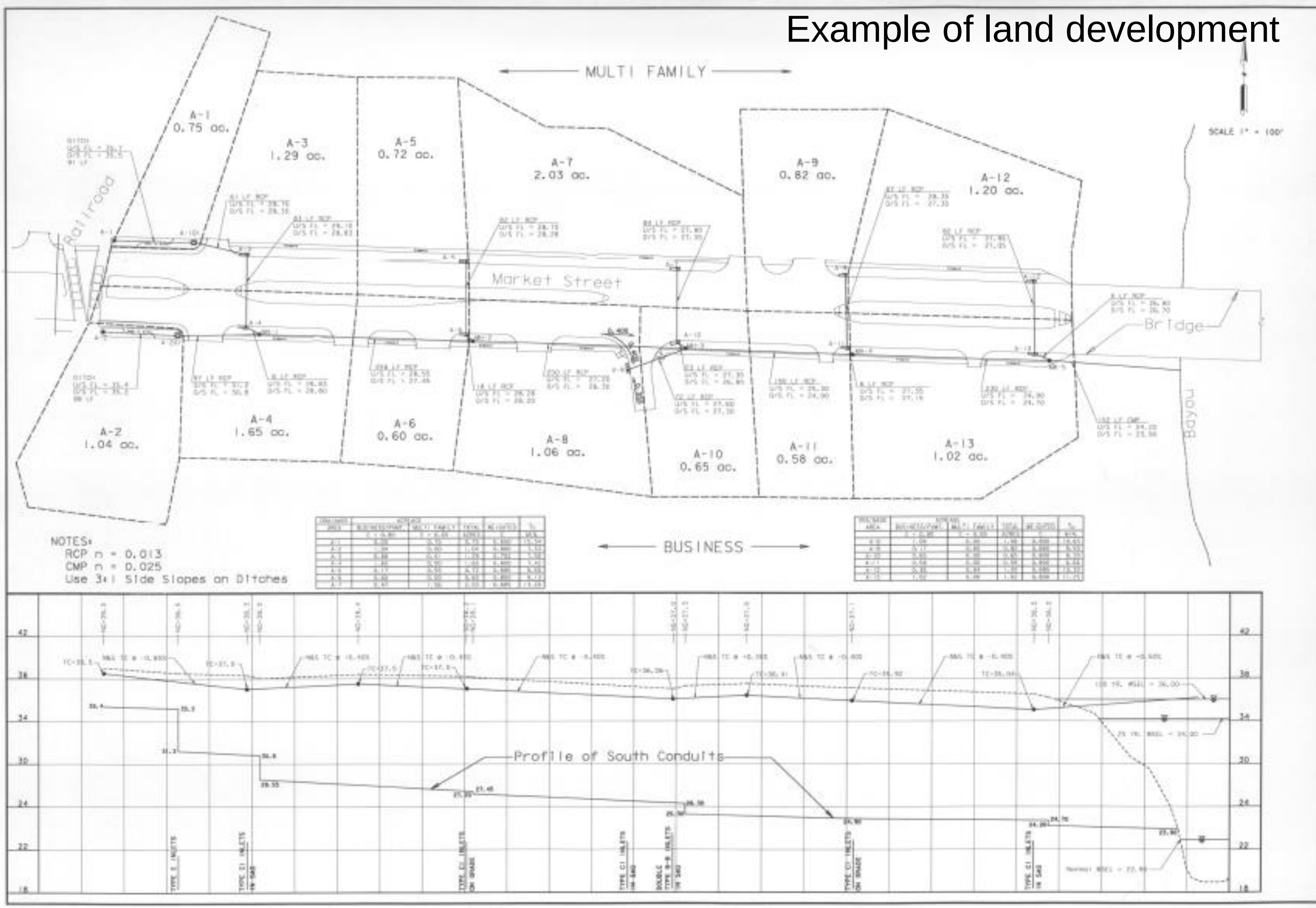
低衝擊開發 的理念及技術必須和開發區的設計及歸劃的步驟相結合，以達到一個成功的開發案。低衝擊開發 的概念其實是很簡單的,所以常被忽視，但他們的重要性卻是無法低估的。**LID** 的步驟-減少開發對水文（蓄水及排水） 所造成的衝擊，若有無法避免的影響，就必須 提供有效的控制方法, 以減少對水文狀態的衝擊。

- Using Hydrology as the Integrating Framework
- Controlling Storm Water at the Source
- Creating Multi-Functional Landscape and Infrastructure

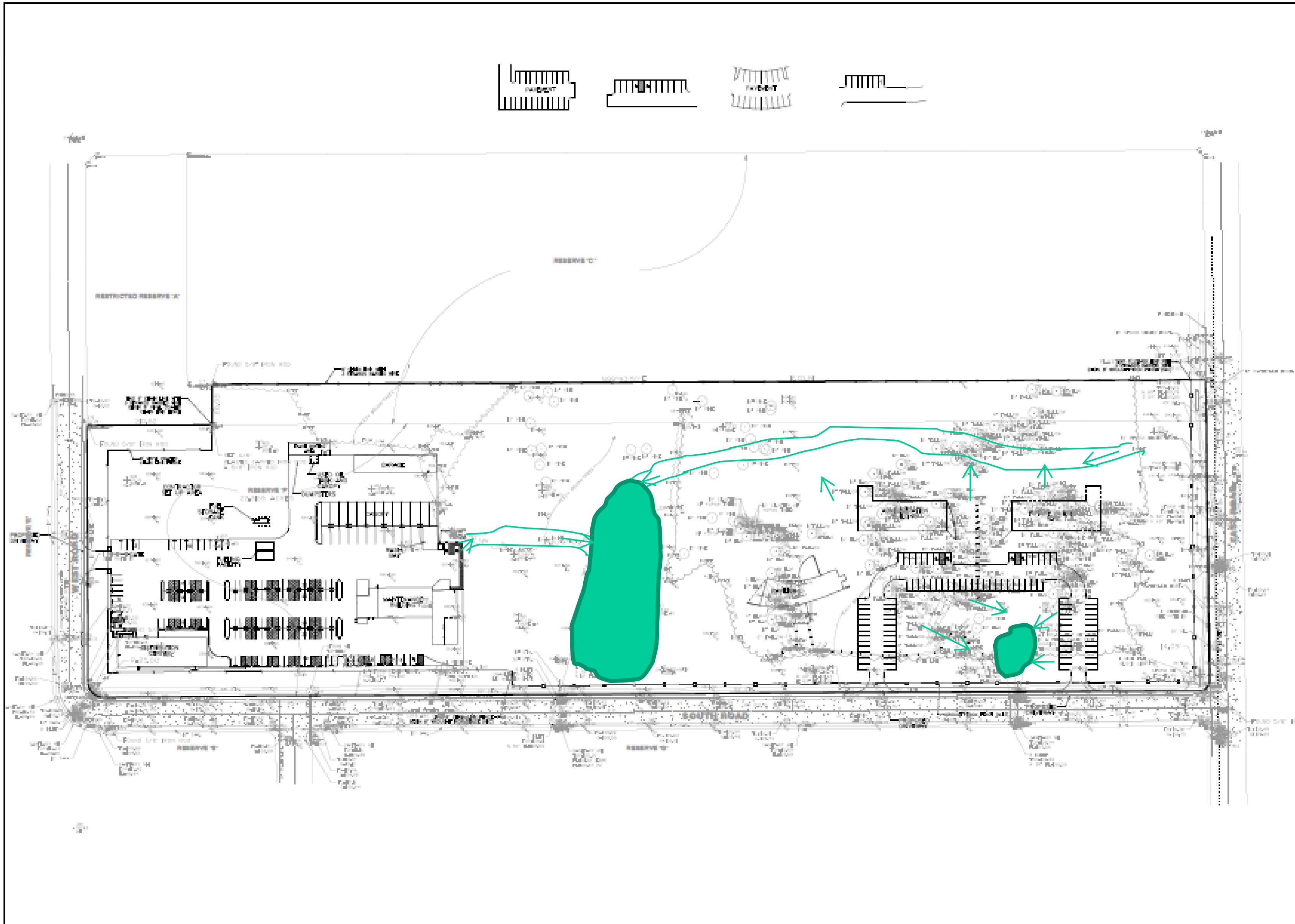
Conventional Development Approach （傳統開發方法）

Drainage Analysis （排水分析）

Example of land development



Example- Design Project



Hydrology （水文）

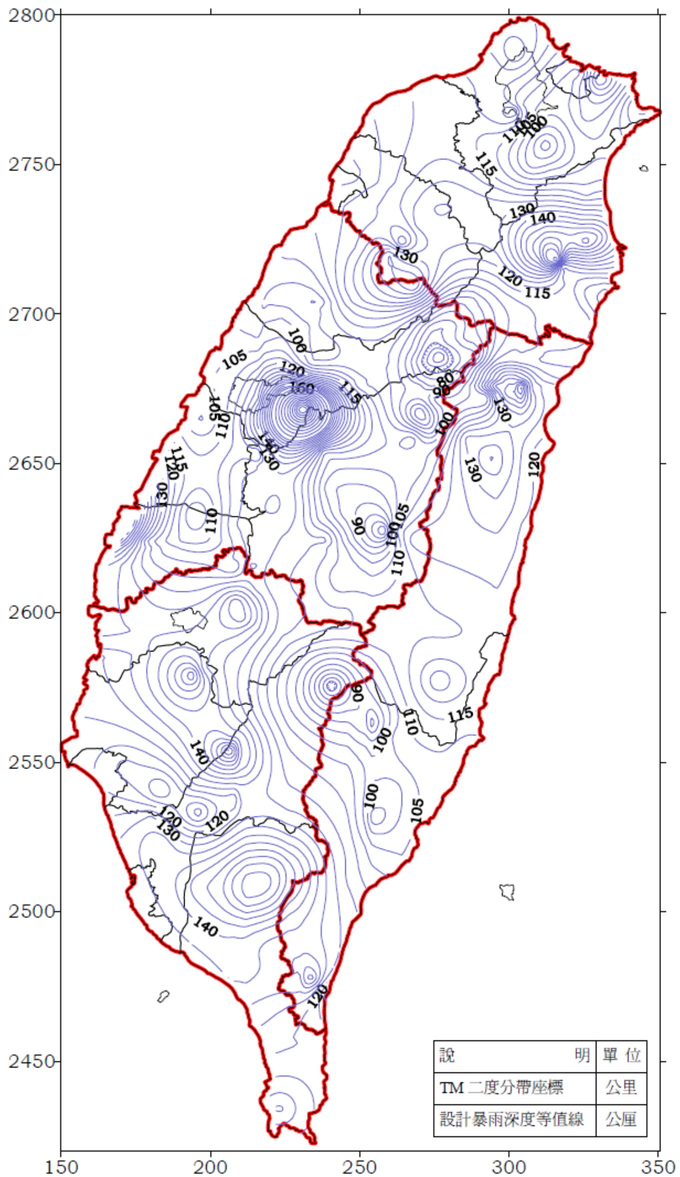
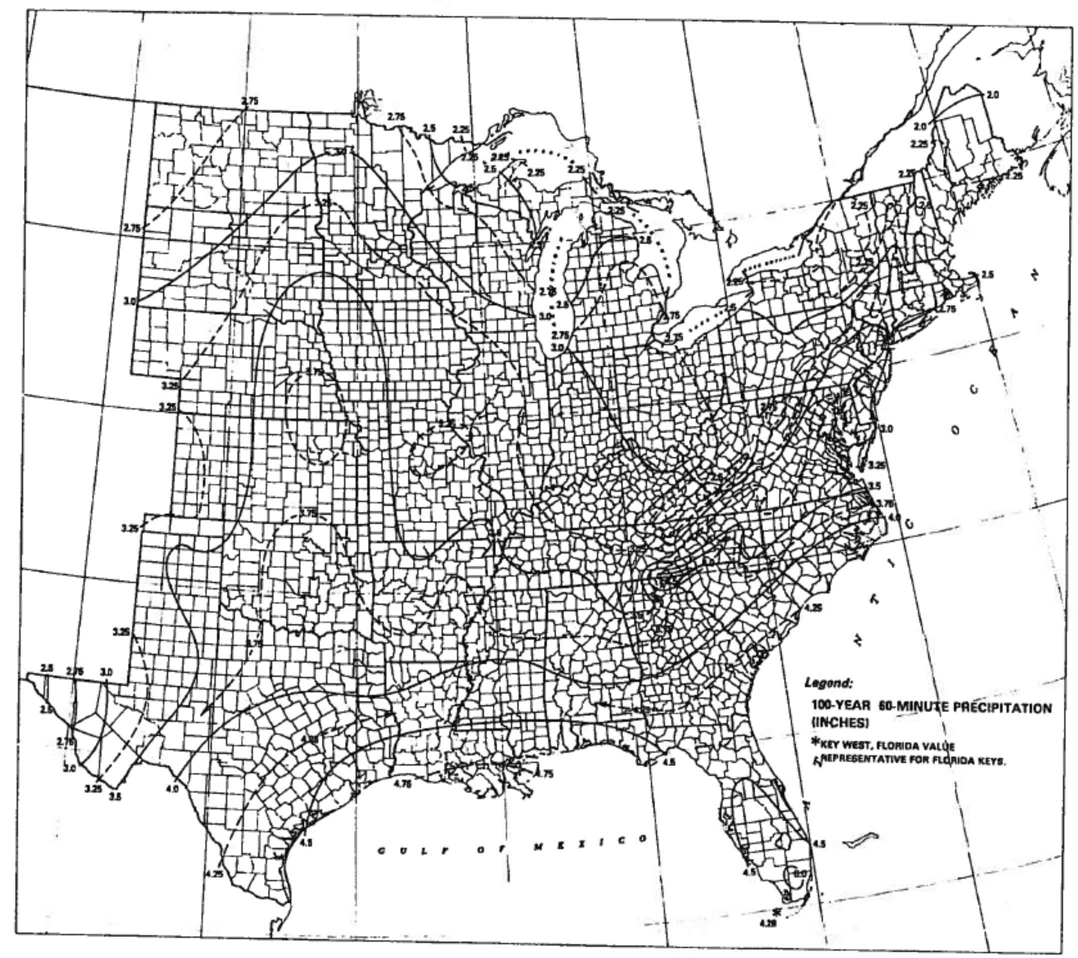


圖 2-30 設計延時 1 小時、重現期距 100 年

Design Rainfall Intensity

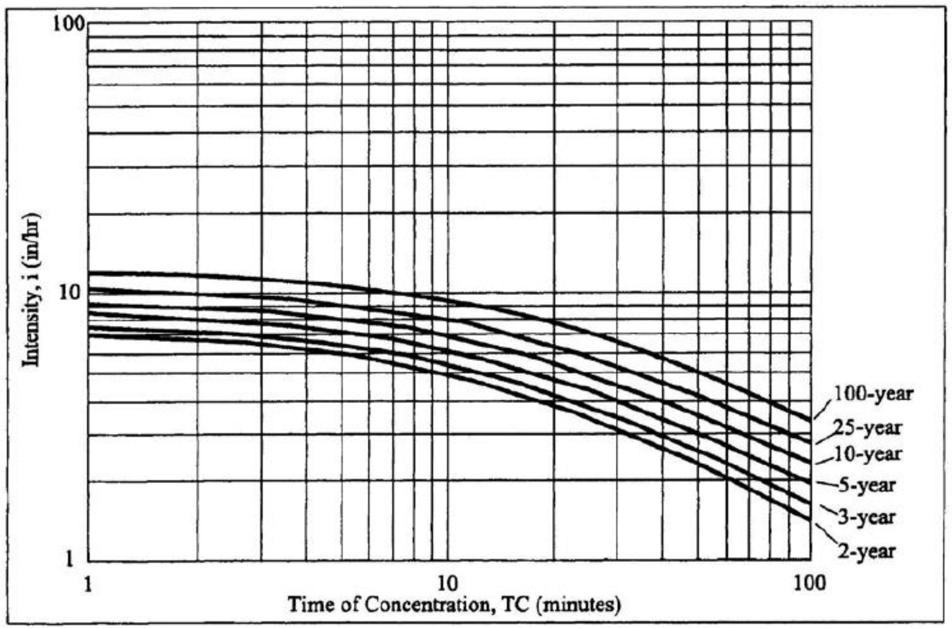
100-year, 60-minute precipitation depths in inches (Frederick, Myers, and Auciello, 1977)



100 year, 60 minutes 降雨強度

Intensity-Duration-Frequency (IDF) Curve

City of Houston IDF Curves
Intensity vs. Time of Concentration vs Rainfall Frequency
Source: Hydro 35/TP-40



$$i=\frac{b}{(d+TC)^{e}}$$

Rainfall Frequency	*b*	*d*	*e*
2-year	75.01	16.2	0.8315
3-year	77.27	17.1	0.8075
5-year	84.14	17.8	0.7881
10-year	93.53	18.9	0.7742
25-year	115.9	21.2	0.7808
100-year	125.4	21.8	0.7500

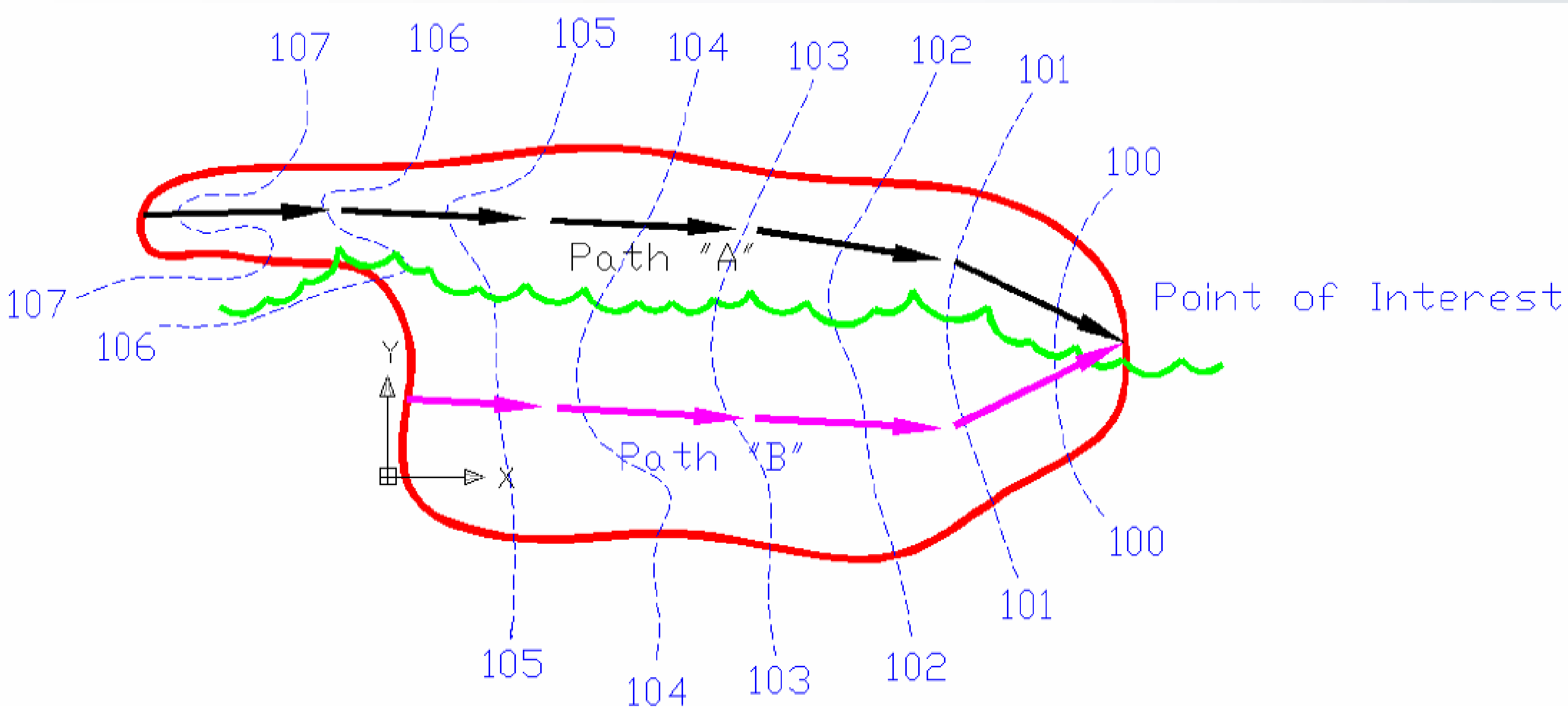
表 1-11 台灣北區雨量站 Horner 公式係數與相關係數

流域名	雨量站名	重現期 / 參數	2 年	5 年	10 年	25 年	50 年	100 年	200 年
冬山河	冬山	a	652.90	997.62	1339.05	2037.46	2950.41	4625.92	8183.97
		b	21.92	29.29	38.65	57.72	79.69	112.10	160.71
		c	0.5375	0.5474	0.5606	0.5875	0.6170	0.6580	0.7151
		R^2	0.9977	0.9961	0.9943	0.9899	0.9845	0.9767	0.9664
冬山河	新寮	a	733.80	799.81	836.96	866.59	873.42	865.99	844.50
		b	22.26	21.02	22.41	25.25	27.65	29.96	31.88
		c	0.5217	0.4796	0.4539	0.4215	0.3968	0.3711	0.3442
		R^2	0.9872	0.9881	0.9896	0.9900	0.9870	0.9784	0.9606
南澳溪	大元山	a	466.41	777.55	1044.31	1461.67	1835.48	2268.32	2775.22
		b	4.85	16.30	26.13	40.37	51.80	63.73	76.23
		c	0.4264	0.4480	0.4652	0.4878	0.5042	0.5203	0.5362
		R^2	0.9977	0.9948	0.9939	0.9936	0.9934	0.9929	0.9919
南澳溪	武塔	a	734.19	617.24	577.40	546.29	530.33	517.71	507.81
		b	24.90	10.84	6.06	2.30	0.40	-1.05	-2.18
		c	0.5542	0.4999	0.4764	0.4547	0.4421	0.4314	0.4222
		R^2	0.9904	0.9971	0.9980	0.9963	0.9936	0.9902	0.9863
南澳溪	樟林	a	886.93	945.94	994.90	1054.50	1091.35	1125.00	1154.17
		b	47.16	45.78	45.60	45.58	45.32	45.06	44.69
		c	0.5363	0.5055	0.4959	0.4884	0.4841	0.4807	0.4777
		R^2	0.9944	0.9842	0.9729	0.9551	0.9406	0.9255	0.9103
淡水河	大豹	a	924.25	1028.55	1163.82	1373.95	1556.91	1766.55	2005.39
		b	16.42	15.25	17.28	21.15	24.67	28.72	33.25
		c	0.6320	0.6055	0.6018	0.6032	0.6070	0.6125	0.6192
		R^2	0.9959	0.9949	0.9955	0.9949	0.9927	0.9889	0.9835
淡水河	中正橋	a	1767.13	2546.37	3290.83	4741.47	6457.74	9137.76	13435.59
		b	17.31	25.03	33.65	49.20	64.86	84.75	109.34
		c	0.7679	0.7679	0.7759	0.7969	0.8204	0.8506	0.8872
		R^2	0.9930	0.9944	0.9966	0.9971	0.9955	0.9928	0.9893
淡水河	五堵	a	1047.46	1155.51	896.53	620.85	486.27	395.15	333.24
		b	23.32	24.02	18.42	9.99	4.34	-0.26	-3.68
		c	0.6505	0.6128	0.5400	0.4457	0.3835	0.3295	0.2833
		R^2	0.9998	0.9957	0.9918	0.9877	0.9856	0.9844	0.9834

$$I=\frac{a}{(b+t_c)^c}$$ (Horner formula)

$$\frac{I_t^T}{I_{60}^{25}}=(G+H\log T)\frac{a}{(b+t)^c}$$ (Dimensionless IDF)

Time of Concentration (tc): Time required for a drop of effective rainfall falling at the most hydraulically remote point in a drainage basin to reach the basin outlet



By Paul Schiariti, Mercer County Soil Conservation District

設計雨型及雨量對時間的分布
（用於逕流對時間分布的計算-Hydrograph)

Table 2 NRCS dimensionless storm distributions (adapted from SCS, 1992)

t (hr)	Type I	Type IA	Type II	Type III
0	0.000	0.000	0.000	0.000
1	0.017	0.020	0.011	0.010
2	0.035	0.050	0.022	0.020
3	0.054	0.082	0.035	0.031
4	0.076	0.116	0.048	0.043
5	0.100	0.156	0.063	0.057
6	0.125	0.206	0.080	0.072
7	0.156	0.268	0.099	0.091
8	0.194	0.425	0.120	0.114
9	0.254	0.520	0.147	0.146
10	0.515	0.577	0.181	0.189
11	0.623	0.624	0.235	0.250
12	0.684	0.664	0.663	0.500
13	0.732	0.701	0.772	0.750
14	0.770	0.736	0.820	0.811
15	0.802	0.769	0.854	0.854
16	0.832	0.801	0.880	0.886
17	0.860	0.831	0.902	0.910
18	0.886	0.859	0.921	0.928
19	0.910	0.887	0.938	0.943
20	0.932	0.913	0.952	0.957
21	0.952	0.937	0.965	0.969
22	0.970	0.959	0.977	0.981
23	0.986	0.980	0.989	0.991
24	1.000	1.000	1.000	1.000

NRCS 24-hour rainfall distribution

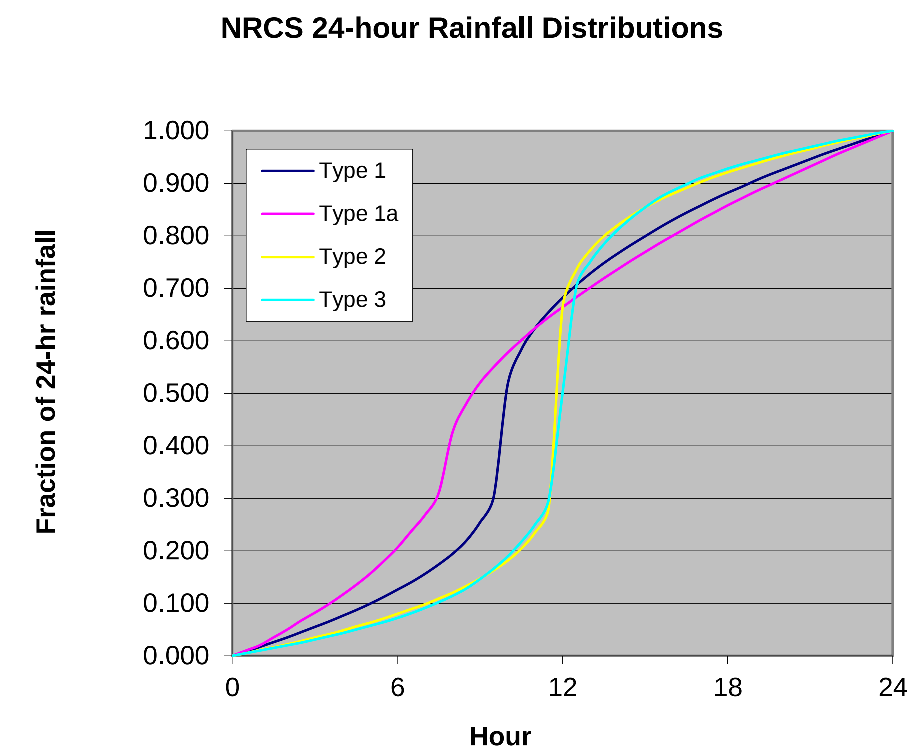
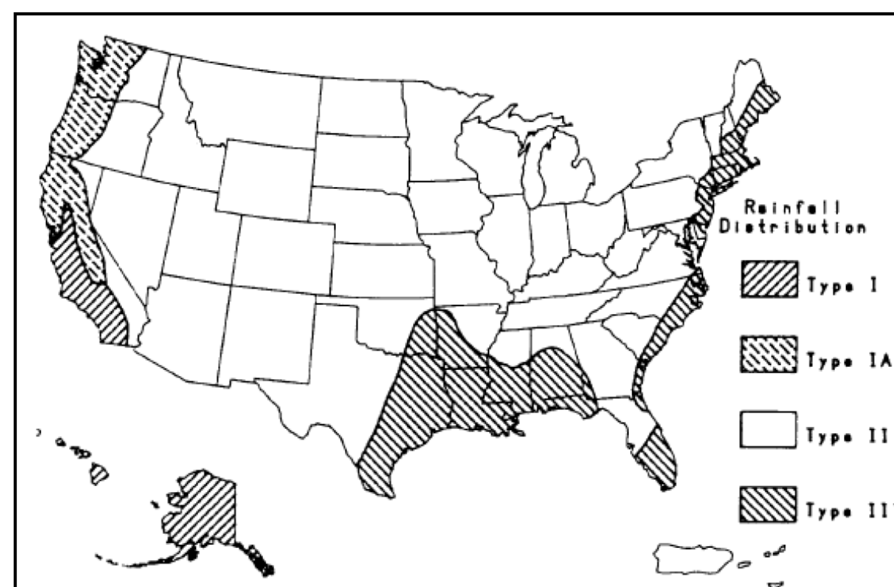
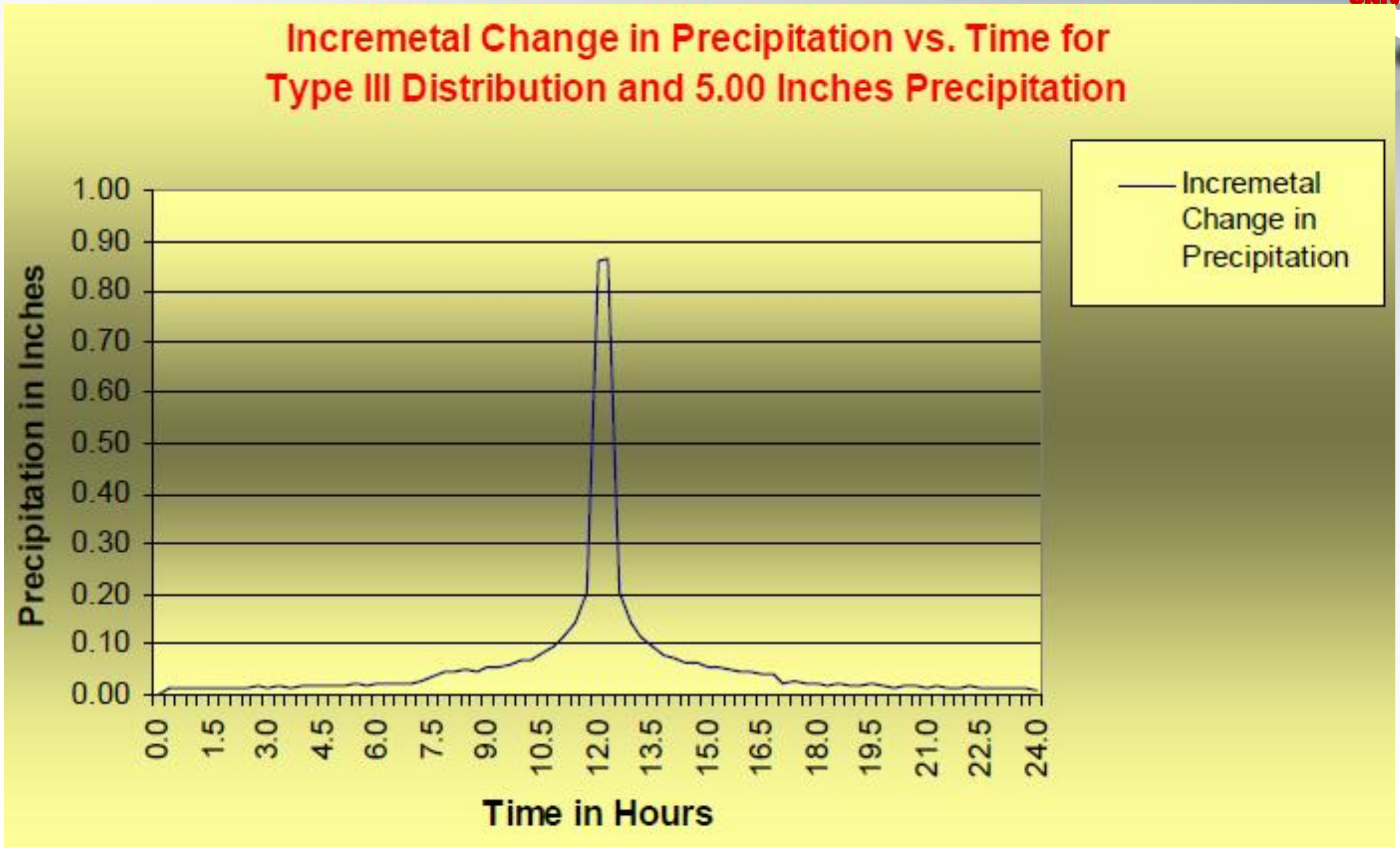


Figure 1: Geographic boundaries for the NRCS rainfall distributions



設計雨型及雨量對時間的分布（**5-in** 總雨量）



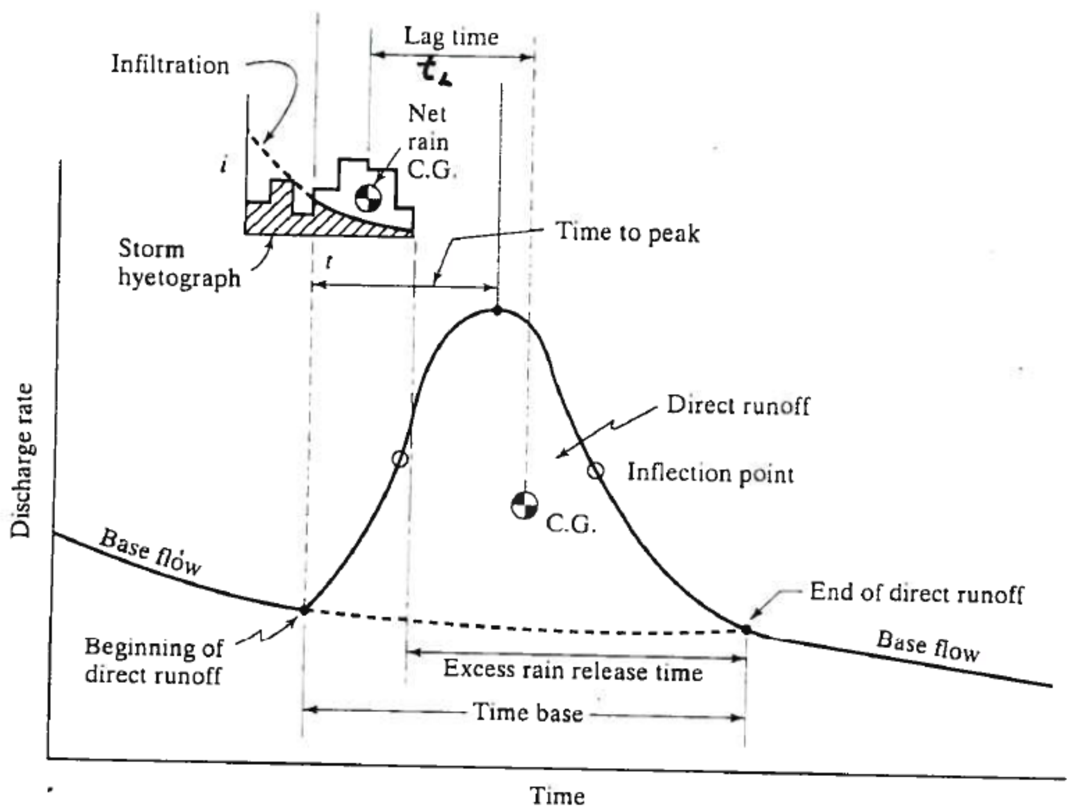
By Paul Schiariti, Mercer County Soil Conservation District

Hydraulics （水理）

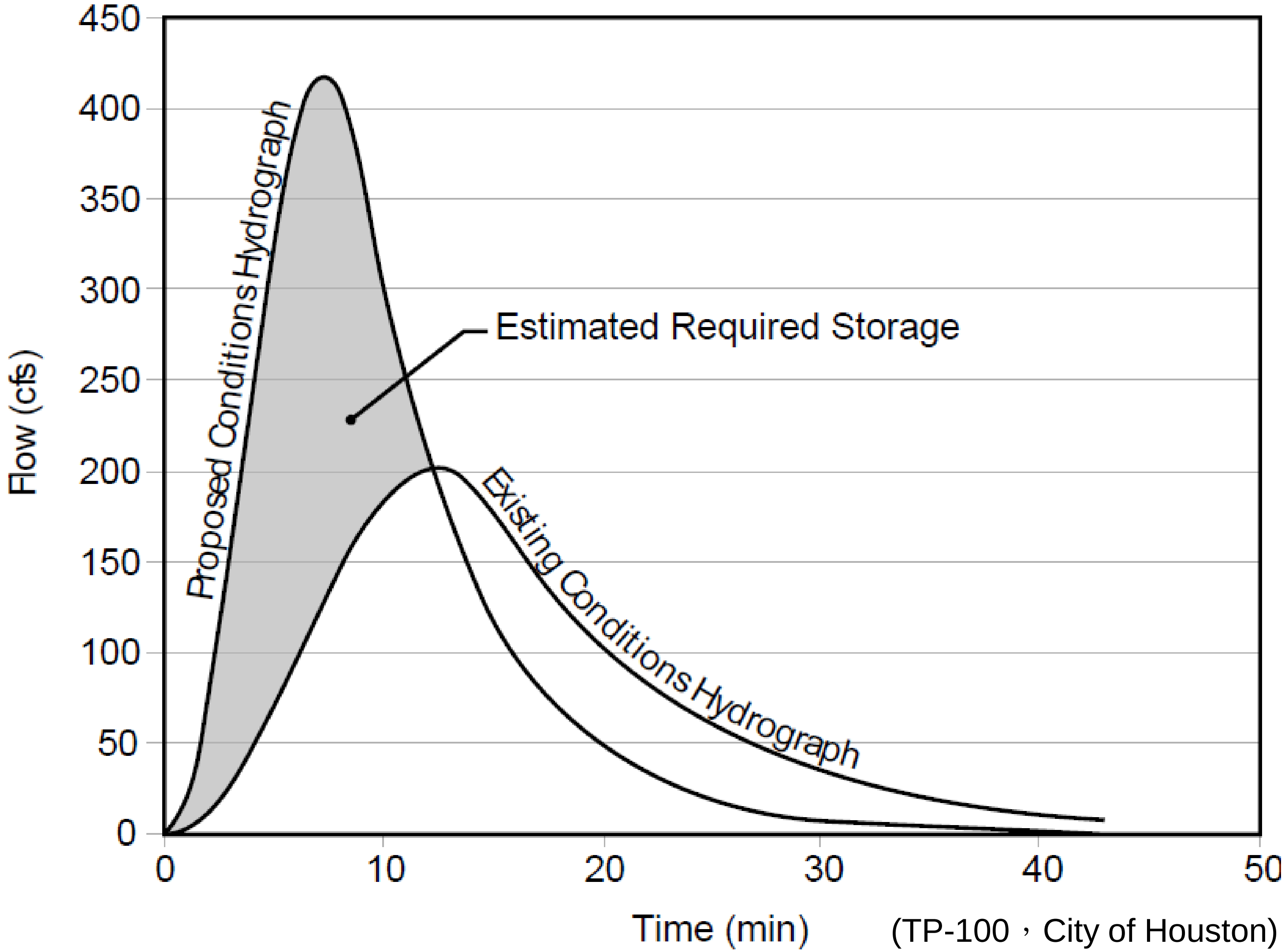
流量計算

Peak Flows –Rational method （合理公式）(Q_p=CiA)

Hydrograph – Synthetic Unit hydrograph, HEC-HMS, SWMM, 單位歷線法（包含無因次曲線法，三角型單位歷線法），貯蓄函數法，水筒模式法, 等。



Estimate detention volume (Small watershed program)



(TP-100，City of Houston)

Detention Pond
蓄洪池

Hydraulic computation for the design of storm sewer pipes and open channels
(設計地下水管道及明渠）

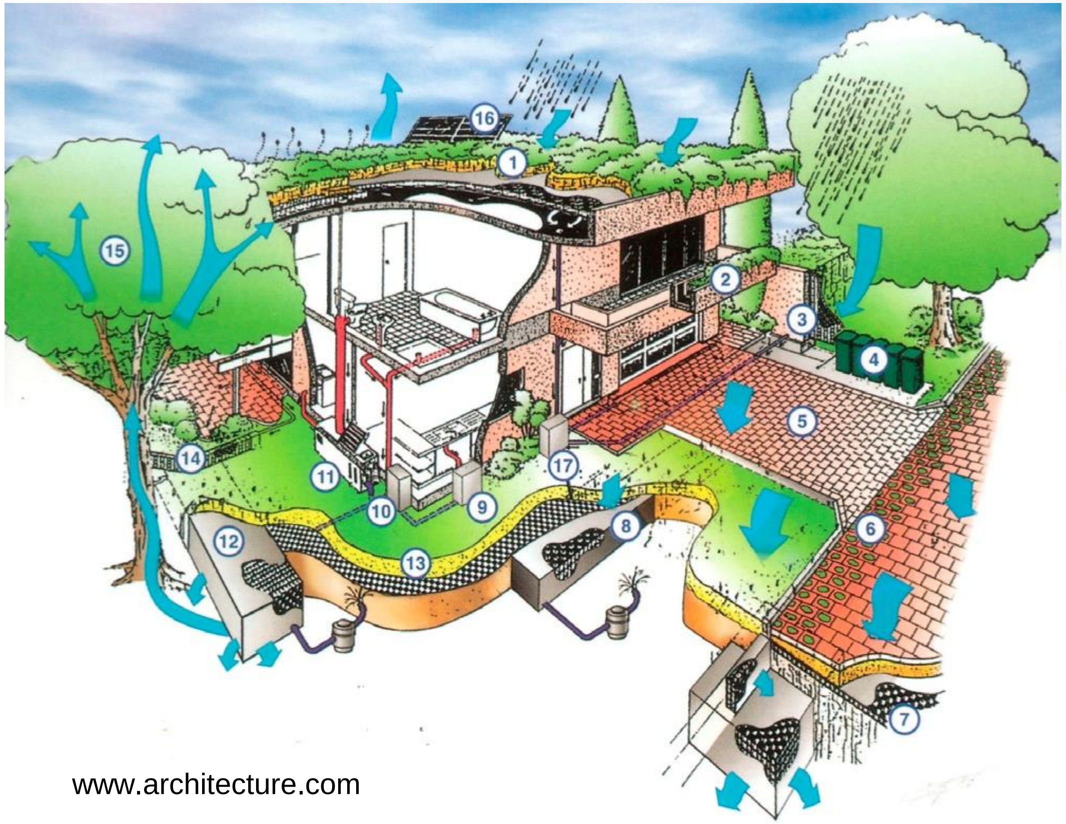
Manning’s formula (曼寧公式）
Energy Equation （能量方程式）

Wildnewjersey.tv

Gutter Flow and Inlet Design
溝槽及進水口

LID Approach（低衝擊開發方法）

在設計雨量計算上和傳統開發（**conventional development)** 的方法上基本上是一致的，但在流量的計算上或模式的運算上就需做一些 修正。修正的因素包含增加地表入滲量，增加地表的粗糙度，增加雨水的集流時間，各區儲蓄水量及其他。以算出的流量和徑流量作為設計的依據。



www.architecture.com

LID-Based Design Criteria （低衝擊開發的設計規範）

- A potential land development option to address drainage, flood control, and storm water quality requirements.
- The adoption of "region-appropriate practices"
- The requirements shall apply to any new development or re-development project choosing to incorporate LID practices for the purpose of satisfying Storm Water Quality Treatment Requirements

Site Acreage	Requirements
Site > 1 Acre	• Treatment of the first 1" of runoff • Storm Water Quality Permit required. • Storm Water Quality Management Plan (SWQMP) required.

- To allow for full development of the property while maintaining pre-development hydrologic functions.

LID 用於開發區設計的概念

- **Integrating Hydrology** （整合水文在設計的考量）

Instead of rapidly and efficiently draining the site, LID relies on various planning tools and control practices to preserve the natural hydrologic functions of the site and minimizing hydrologic impacts

Integration of hydrology into the site planning process begins by Identifing sensitive areas that affect hydrology. The process also

- Define the Development Envelope.
- Minimize total impervious area.
- Disconnect Impervious surfaces.
- Control and breakup impervious areas with Integrated Management Practices (IMPs).

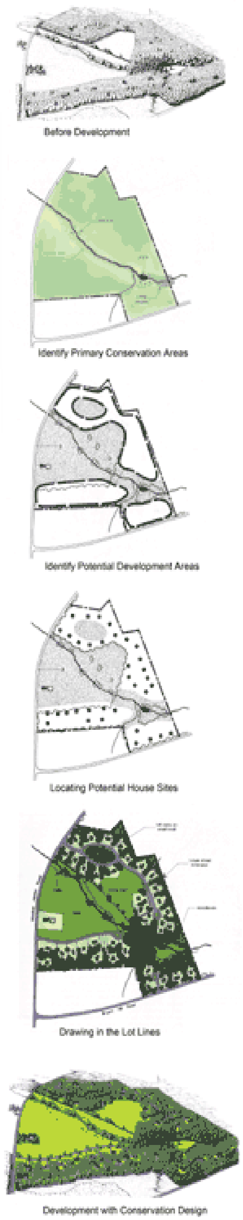
- **Controlling Storm Water at the Source（降雨及排水源頭的管制）**

LID IMPs implemented on small drainage areas allow for a distributed control of storm water throughout the entire site. This process offers significant opportunities for maintaining the site's key hydrologic functions including infiltration/biofiltration, depression storage, and interception, as well as an increase in the time of concentration. The key to restoring the predevelopment hydrologic functions is to minimize and then mitigate the hydrologic impacts of land use activities closer to the source of generation.

- **Creating Multi-Functional Landscape and Infrastructure（創造出多元及實用的景觀和基礎工程結合的設計）**

LID offers an innovative alternative approach to urban storm water management that uniformly or strategically integrates storm water controls into multifunctional landscape features where runoff can be micromanaged and controlled at the sources. LID may allow a variety of urban landscapes or infrastructure feature (roof, streets, parking, sidewalks, collection/conveyance systems and green space) to be designed to be multifunctional, incorporating detention, retention, filtration, or runoff use, where feasible.

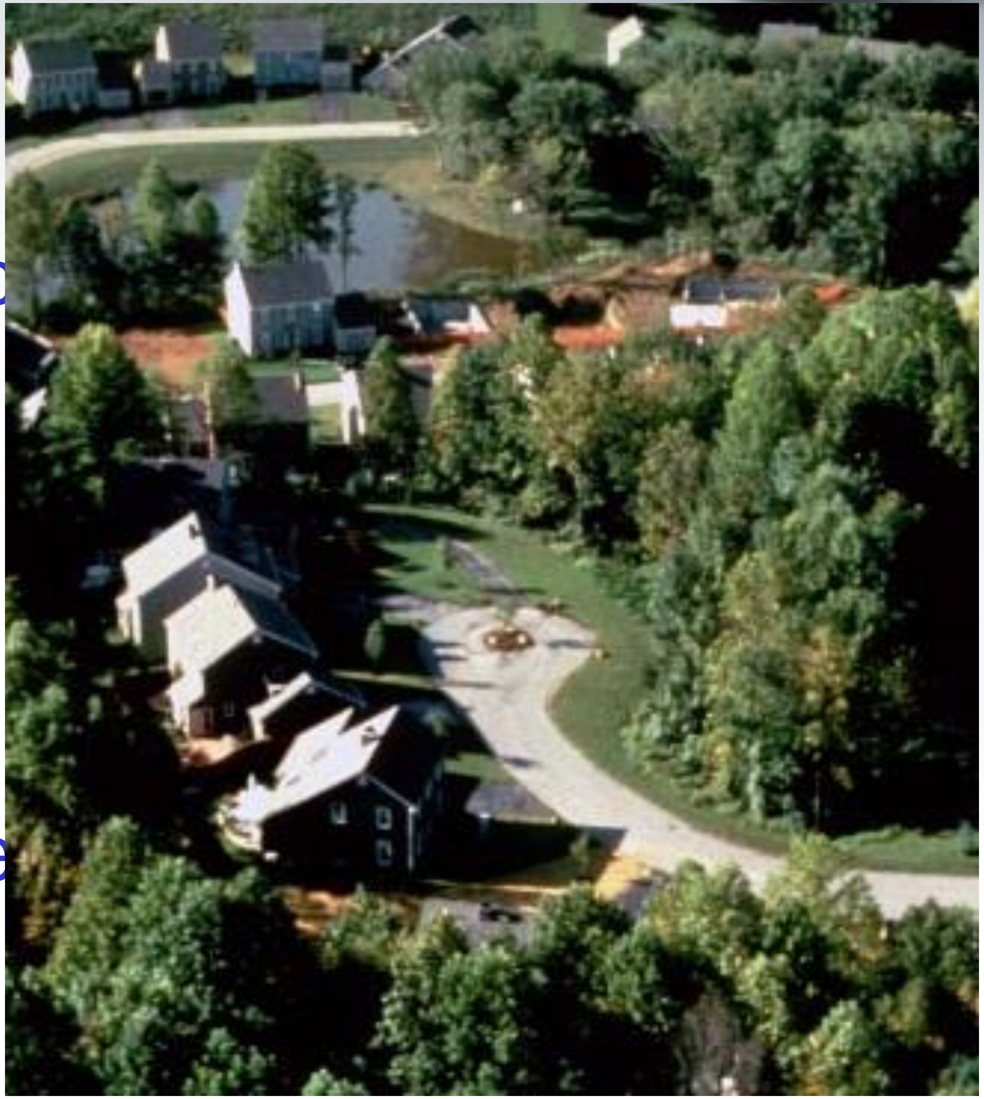
LID Site Design



- Conservation of natural hydrology, trees, and vegetation
- Minimized impervious surfaces
- Dispersal of stormwater runoff
- Conservation of stream & wetland buffers
- Ecological landscaping

Site Design Practices

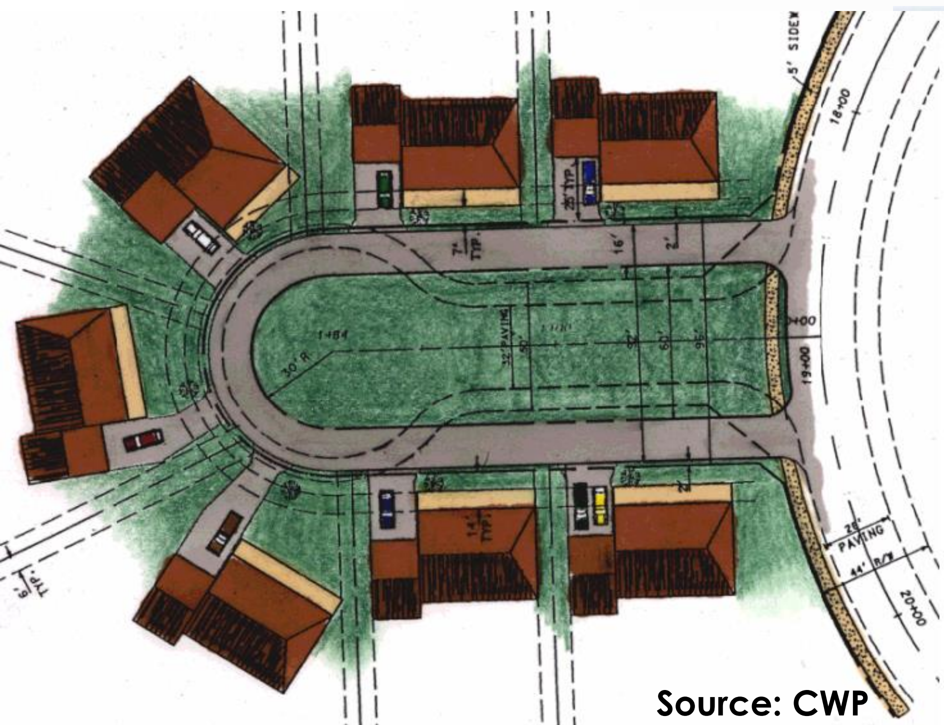
- Reduce storm pipes, curbs and gutters
- Preserve sensitive soils
- Cluster buildings and reduc building footprints
- Reduce road widths
- Minimize grading
- Limit lot disturbance
- Reduce impervious surface
- Reduce pond size

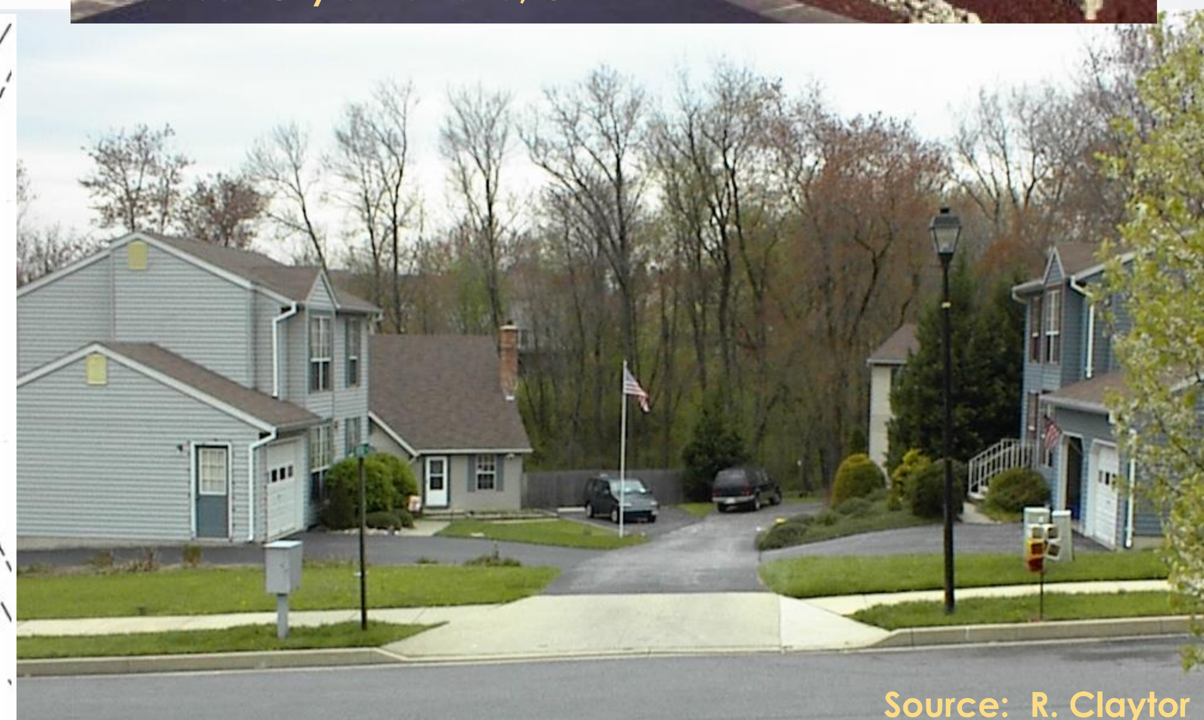


Better Site Design on Roadways and Driveways

- Narrower streets
- Alternative cul-de-sacs
- Shared driveways


Source: City of Portland, OR


Source: CWP


Source: R. Claytor

LID Options (Unlimited)

- Bioretention/Rain Gardens
- Strategic Grading
- Amended Soils
- Resource Conservation
- Flatter Wider Swales
- Flatter Slopes
- Tree/Shrub Depression/Filtration
- Turf Depression Storage
- Landscape Island Storage/Filtration
- Rooftop Detention/Retention
- Roof Leader Disconnection
- Parking Lot/Street Storage/Filtration
- Smaller Culverts, pipes & Inlets
- Alternative Surfaces & Building Materials
- Reduce Impervious Surface
- Surface Roughness Technology
- Rain Barrels/Cisterns/Water Use
- Catch Basins/Seepage Pits
- Sidewalk Storage
- Infiltration Swales & Trenches
- Tree Box Filters
- Trash Collectors
- Maximize Sheet flow
- Tree Planting & Landscaping
- Reforestation
- Pollution Prevention

Acceptable LID IMPs for Storm Water Management (storm water quality and detention requirements) **and Mitigation Credit**

IMP	Effect or Function					
	Slow Runoff	Filtration	Retention	Detention	Evaporation	Water Quality
Disconnection	X	X				X
Soil Amendment		X				X
Vegetated Filter Strip	X	X			X	X
Vegetated Swale	X	X		X	X	X
Rainwater Harvesting			X	X		X
Bioretention	X	X		X	X	X
Permeable Pavement	X	X		X	X	X
Tree Box Filter	X			X		X
Storm Water Planter	X	X		X	X	X
Green Roof	X				X	X

LID Stormwater Techniques

- Rainwater Harvesting （雨水收集設施）
- Vegetated Filter Strip （植生過濾帶）
- Vegetated Swale （低窪植生溝渠）
- Permeable Pavement （滲水鋪面）
- Tree Box （樹箱）
- Stormwater Planters （雨水流經植栽區）
- Bioretention （生態蓄流池）
- Green Roof s

（綠色（植生）屋頂）

- Stormwater Wetlands （濕地）
- Dry/Wet Detention Pond

  （乾濕儲水池）

UNIVERSITY of HOUSTON

Rainwater Harvesting (雨水收集設施）

- Designed to capture roof runoff for reuse (收集屋頂雨水及再使用）.
- Includes cisterns, rain barrels, and underground storage systems.
- Provide a means for water storage (detention) to serve irrigation purposes and may factor into a water conservation

設計要求

- Acceptable for water quality and detention on the commercial site or non-single family residential structures.
- Development of a water budget shall be conducted to show how volume is made available for detention.
- Storage capacity must be designed to assure capacity is available in multiple rain events.
- Not typically accepted for detention purposes.

Rain Barrels and Cisterns
Runoff Reduction & Water Conservation

- Downspouts directed to tanks or barrels
- 50 –10,000 gallons
- Excess diverted to drywell or rain garden
- Landscaping, car washing, other non-potable uses

Commercial building
(at Houston Medical Center)

single family house

Underground stromwater storage system
(underground detention)

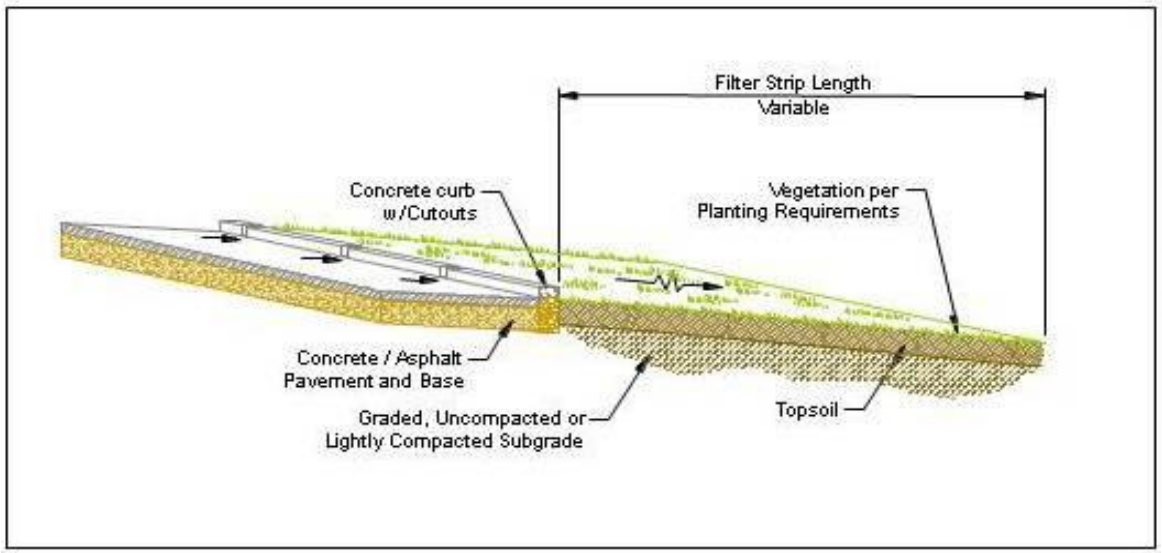
www.conteches.com

www.onekidsplace.ca

www.kanapipeline.com

Vegetated Filter Strip（草植物過濾帶）

A vegetated Filter Strip is a band of dense vegetation, usually grass, planted between a pollution source (e.g., roadway, rooftop downspout, etc.) and a downstream receiving water body or conveyance.



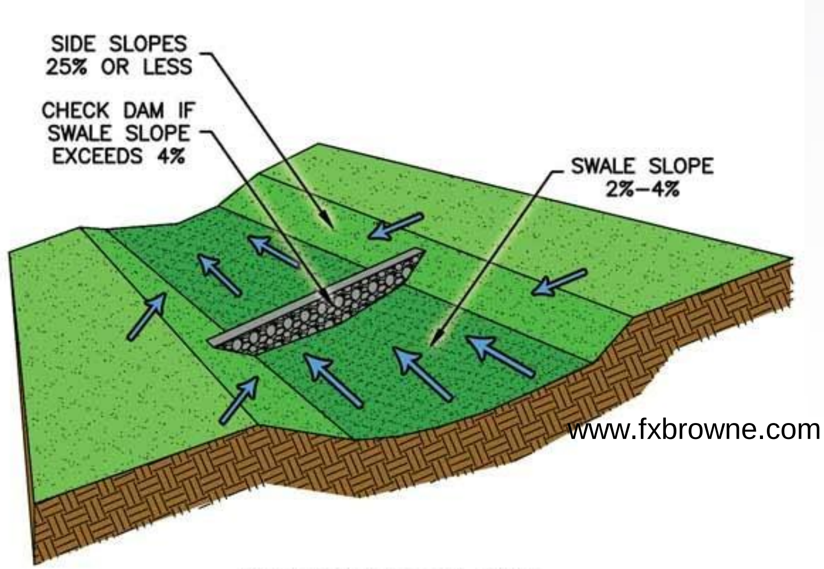
設計要求

The longest flow path to a filter strip, without the installation of energy dissipaters and/or flow spreaders, should not exceed 75 feet for impervious ground cover and 150 feet for pervious ground cover.

（**Soil Amendment**，**Vegetation Considerations**，**Maintenance Requirements**）

Vegetated Swale （低窪植生溝渠）

Vegetated Swales are broad, shallow channels designed to convey and filter storm water runoff while slowing runoff and removing gross pollutants. They handle runoff from small drainage areas at low velocities.



VEGETATED (grassed) SWALE
FIGURE 2A
*not to scale

設計要求

The bottom and sides of the swale must be vegetated. Surface ponding in a vegetated swale must not exceed 24 hours, however a longer time frame may be considered to match existing conditions hydrograph.

Vegetated Swales
Conveyance, Treatment, Infiltration

- Roadside swales ("country drainage") for lower density and small-scale projects
- For small parking lots
- Mild side slopes and flat longitudinal slopes
- Provides area for runoff storage & treatment

Permeable Pavement （滲水鋪面）

Permeable pavement includes a wide range of paved or load-bearing surfaces that allow water to pass rapidly through the surface and into the sub-grade that serves as a reservoir, a filter bed, and a load- bearing layer.

設計要求

• Permeable pavement systems must be designed to incorporate an underdrain, or a subsurface detention or retention system with the capacity to drain the surface of the system within 24 hours.

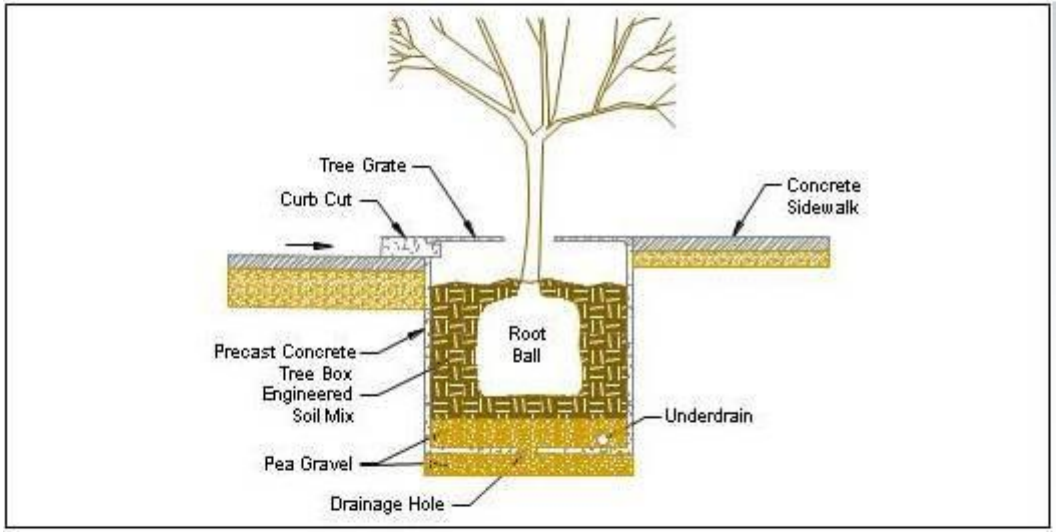
•Storage in aggregate or underground structures may be located beneath the paving system to provide detention volume, but these systems must include a liner.

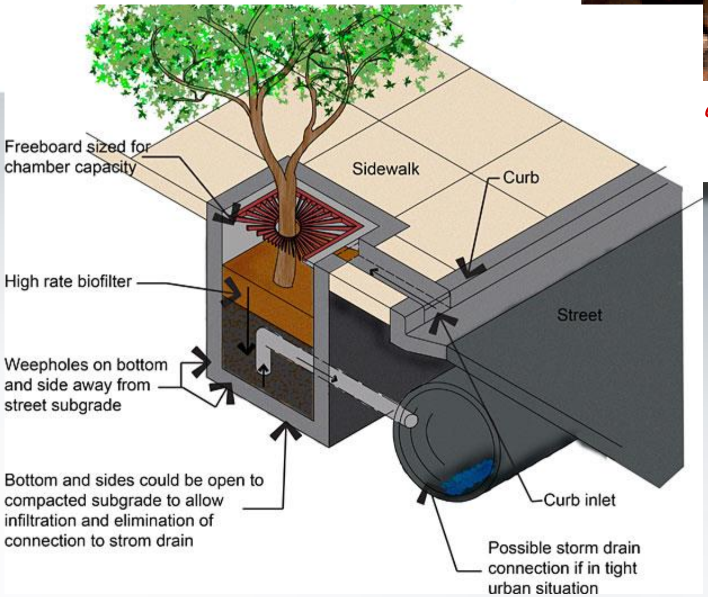
• Permeable pavements are not allowed on driveway aprons, or public streets (Limited to lightly traveled surfaces (i.e. parking pads in parking lots, trails and sidewalks)).

• Voids in the permeable concrete itself may not be counted as detention volume.

Permeable Pavement

Tree Box （樹箱）





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www.Ciceet.unh.edu

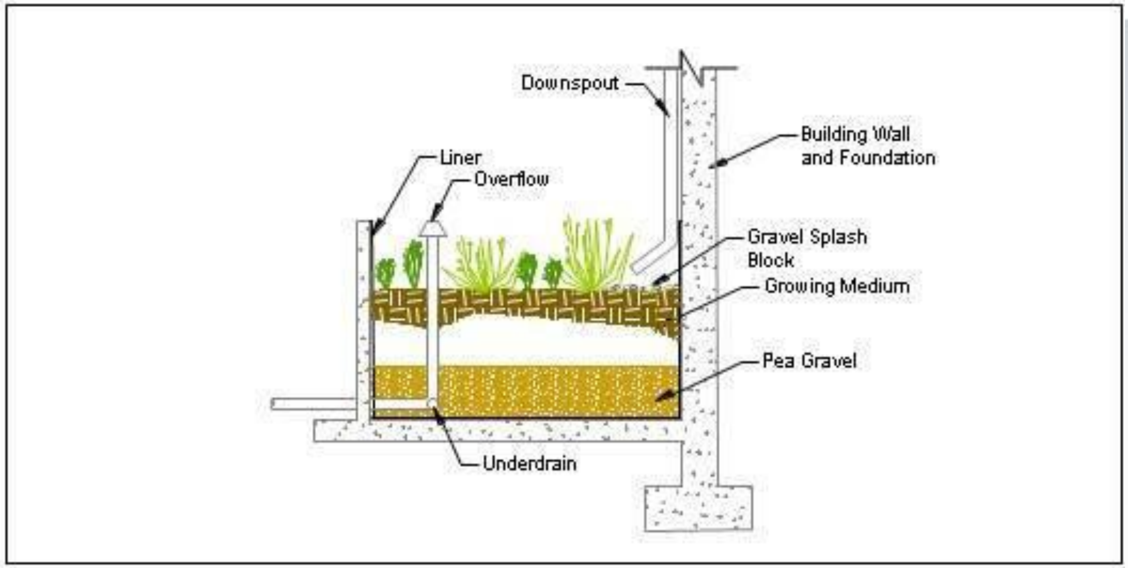
設計要求

The ponding area in Tree Box Filters shall be designed with a maximum ponding depth of 24" and to drain ponded water within 24 hours.

An underdrain pipe is required to drain the feature.

A maximum of 75% of the void space volume may be counted for detention.

Stormwater Planters （雨水流經植栽區）

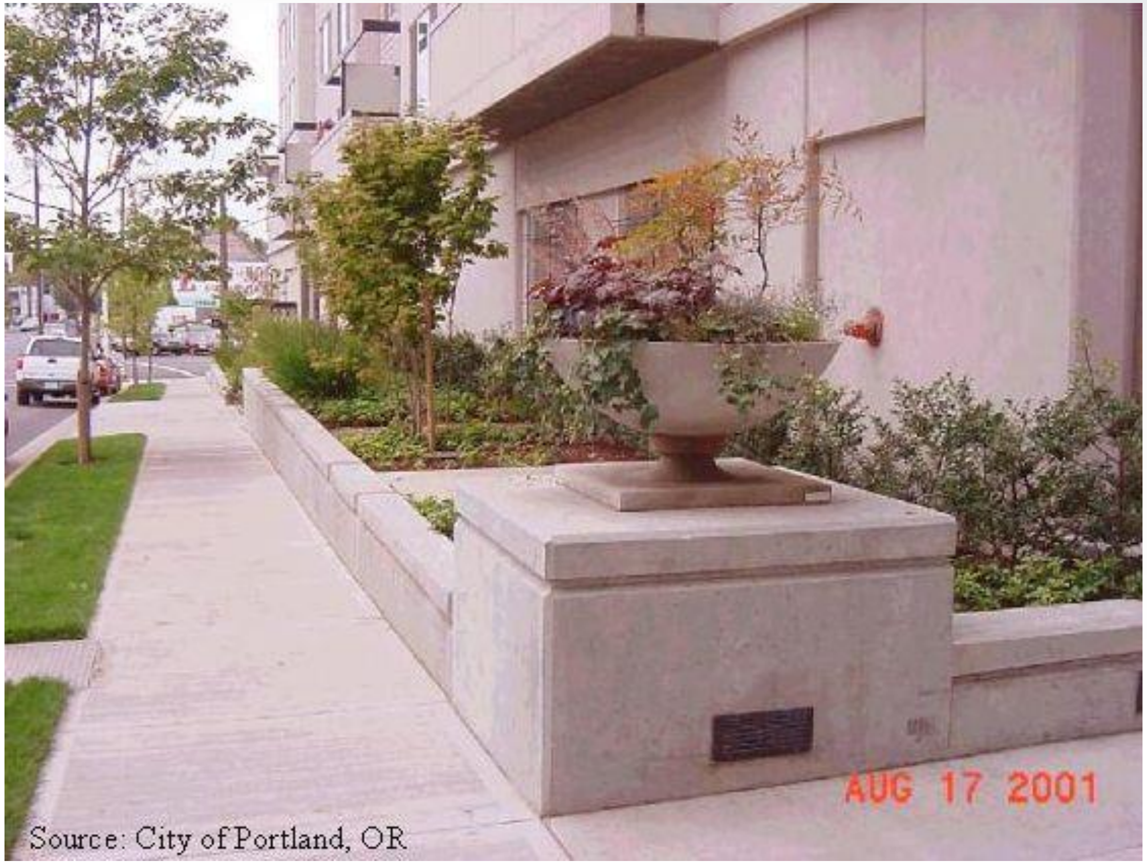


Storm Water Planters, also known as flow through planters, are also <u>bioretention systems</u> in enclosed in concrete structures. They can be designed to drain runoff from paved areas via curb inlet structures or pipes, or they can be located under roof drain downspouts for treatment of roof runoff.

設計要求

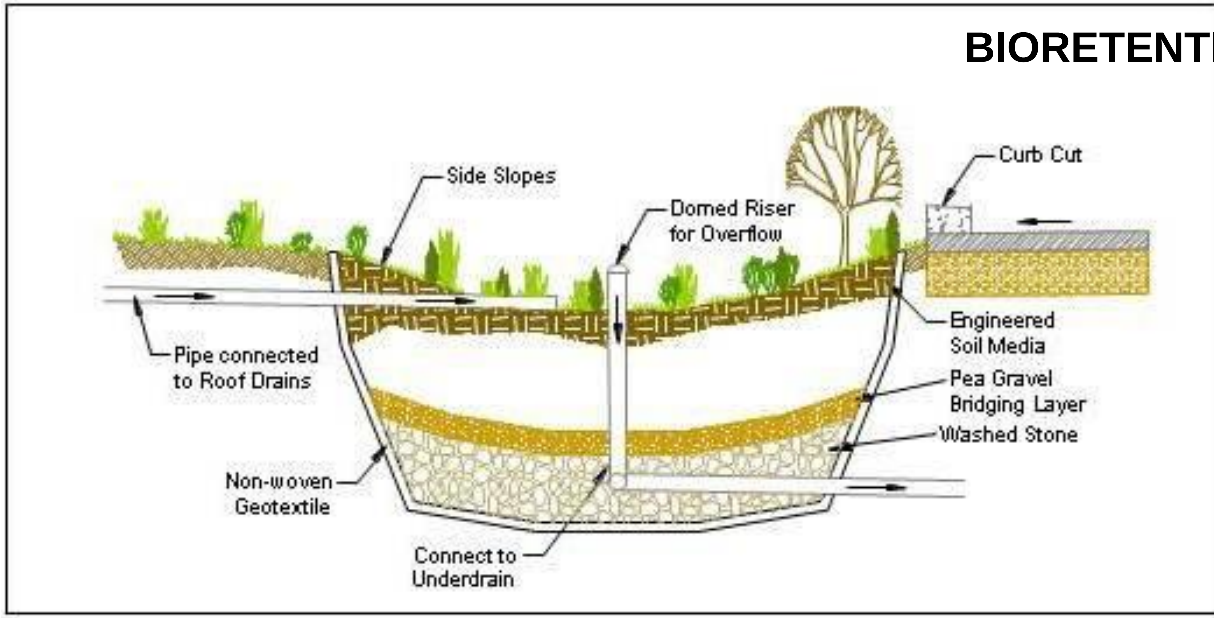
- Storm Water Planters shall be designed with an underdrain pipe.
- Waterproofing shall be incorporated into the designs of Storm Water Planters sited near buildings and other structures.
- The ponding area in Storm Water Planters shall be designed with a maximum ponding depth of 24” and to drain ponded water within 24 hours.

Stormwater Planters



- Vegetative uptake of stormwater pollutants
- Pretreatment for suspended solids before they reach water-treatment facilities
- Aesthetically pleasing
- Reduction of peak discharge rate

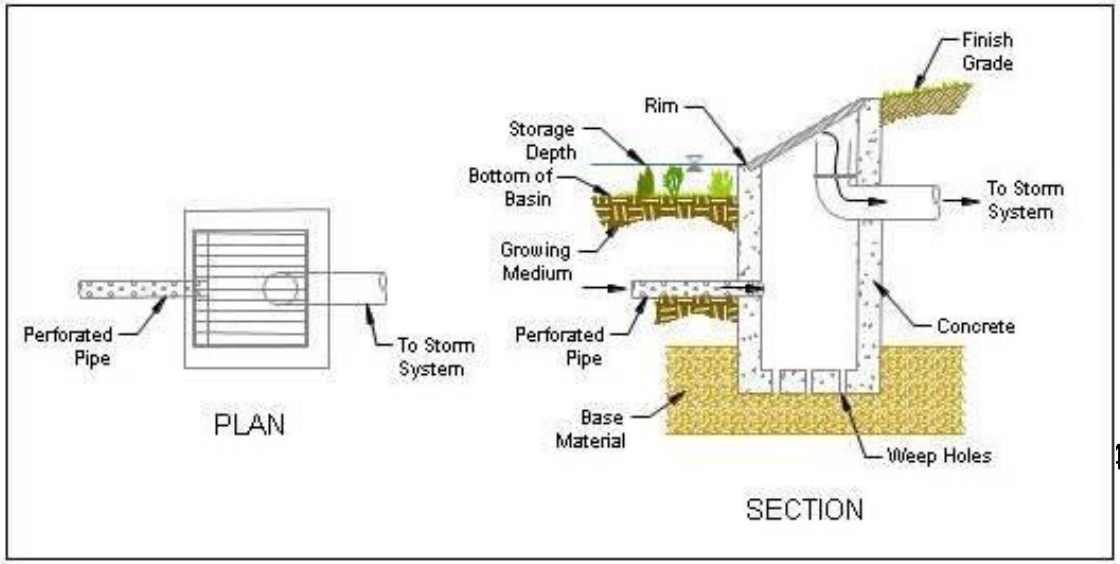
Bioretention（生態蓄流池）



BIORETENTION SYSTEM COMPONENT

- Geotextile Filter Fabric
- Engineered/Amended Soil
- Vegetation
- Aggregate
- Underdrain
- Observation/Cleanout Standpipe
- Overflow structure
- Storage Chamber Products
- Outfall Structure
- Surface Ponding (ponding depth of 2ft for the 2yr event and 4ft for the 100yr event)

Bioretention is a water quality and water quantity control practice using the chemical, biological and physical properties of plants, microbes and soils for biofiltration and the removal of pollutants from storm water runoff. （Bioretention Cells, or Rain Gardens）



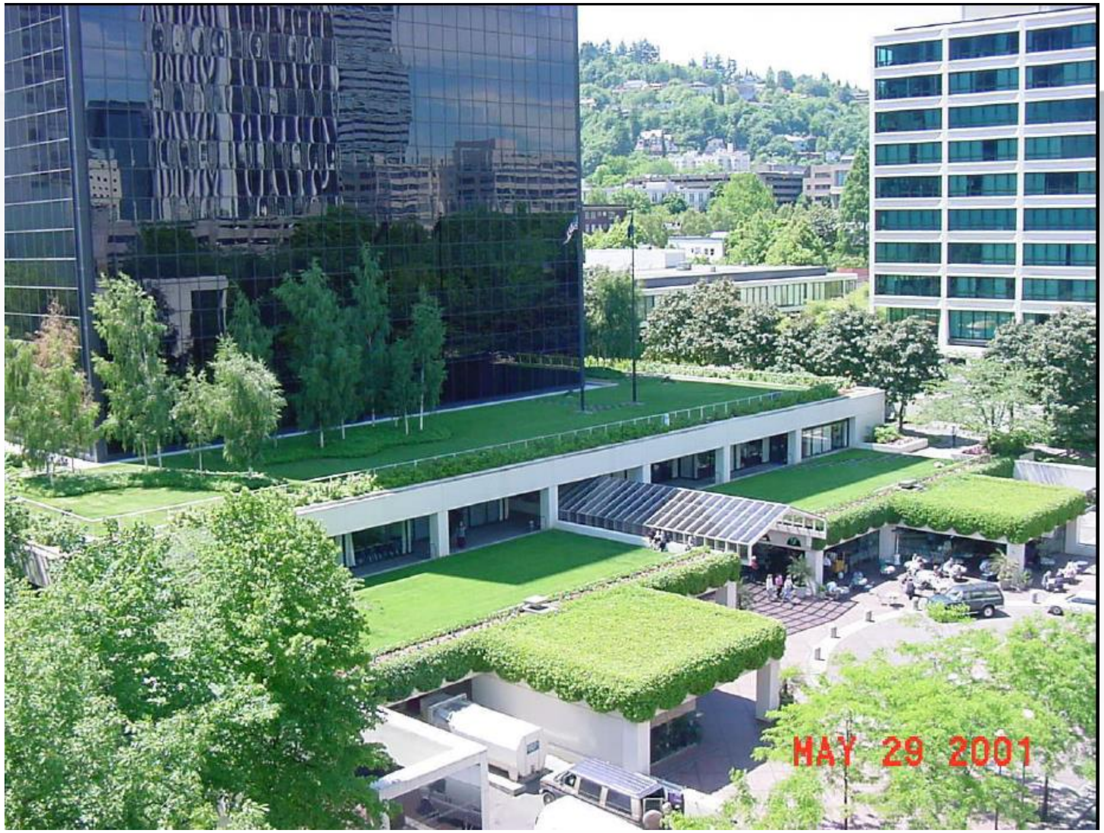
Bioretention Applications

- Parking lot islands
- Median strips
- Residential lots
- Office parks

Source: City of Portland, OR

Source: LID Center

Green Roofs （綠色（植生）屋頂）



A green roof is a vegetated roofing system. Green roofs typically consist of a number of layers: a waterproofing membrane, a drainage system, root protection, growing media (soil) and vegetation. Green roofs provide numerous environmental benefits and offer a valuable tool for integrated storm water management.

Green roofs can provide an acceptable storm water quality treatment on the commercial site or non-single family residential structures.

Green Roofs

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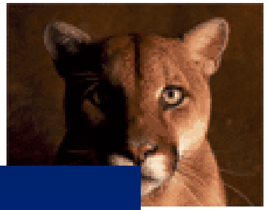
World Trade Center, Boston
Photo: ©2005 Roofscapes, Inc.

- Stormwater Runoff absorption/collection
- Reduced flooding of and damage to urban streets
- Interior heating and cooling benefits of 10 degrees or more
- Air purification
- Recreational amenity
- Improved aesthetics
- Extended roof life, estimated at 40 years

Case Studies

Sommerset Subdivision

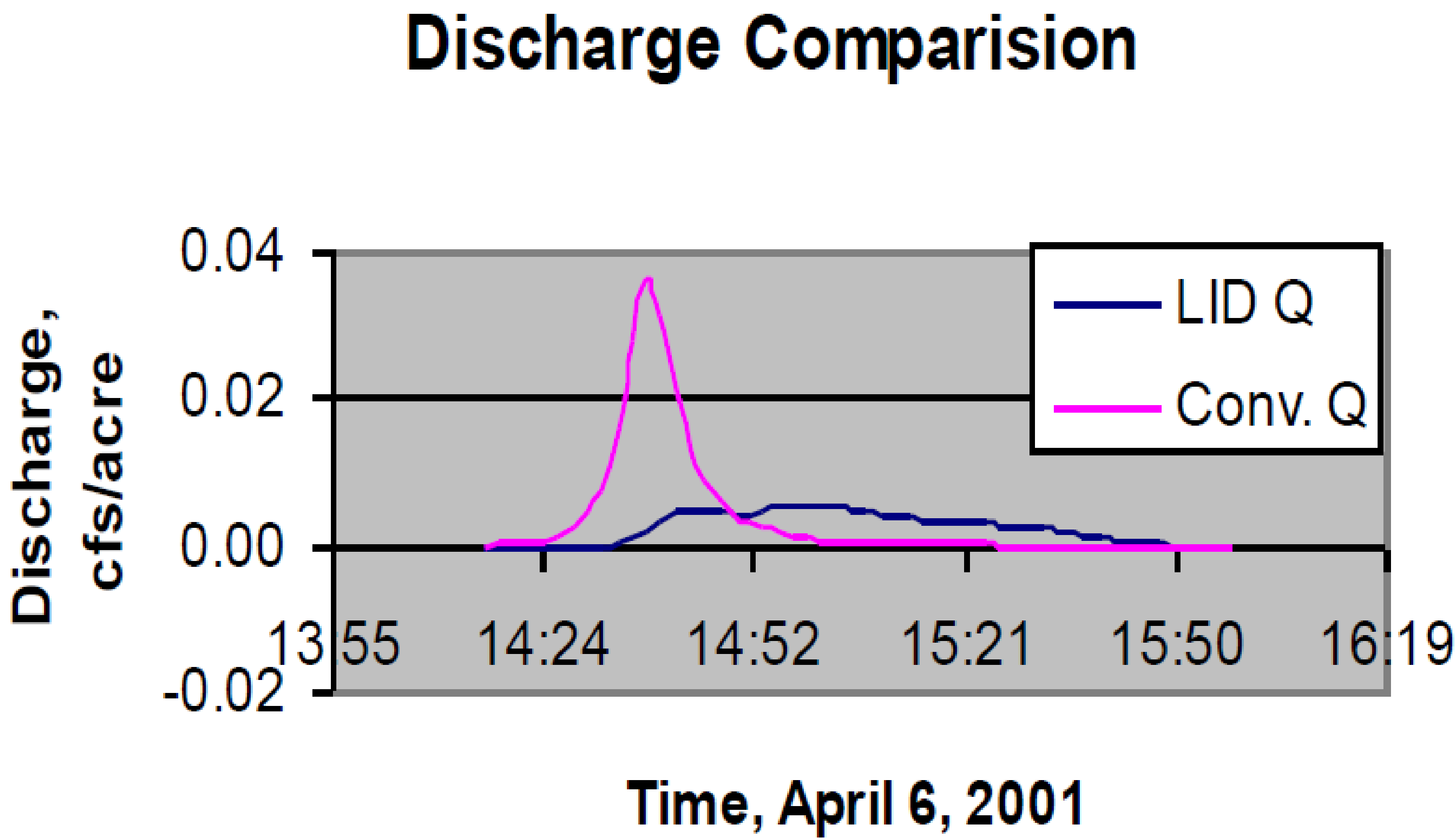


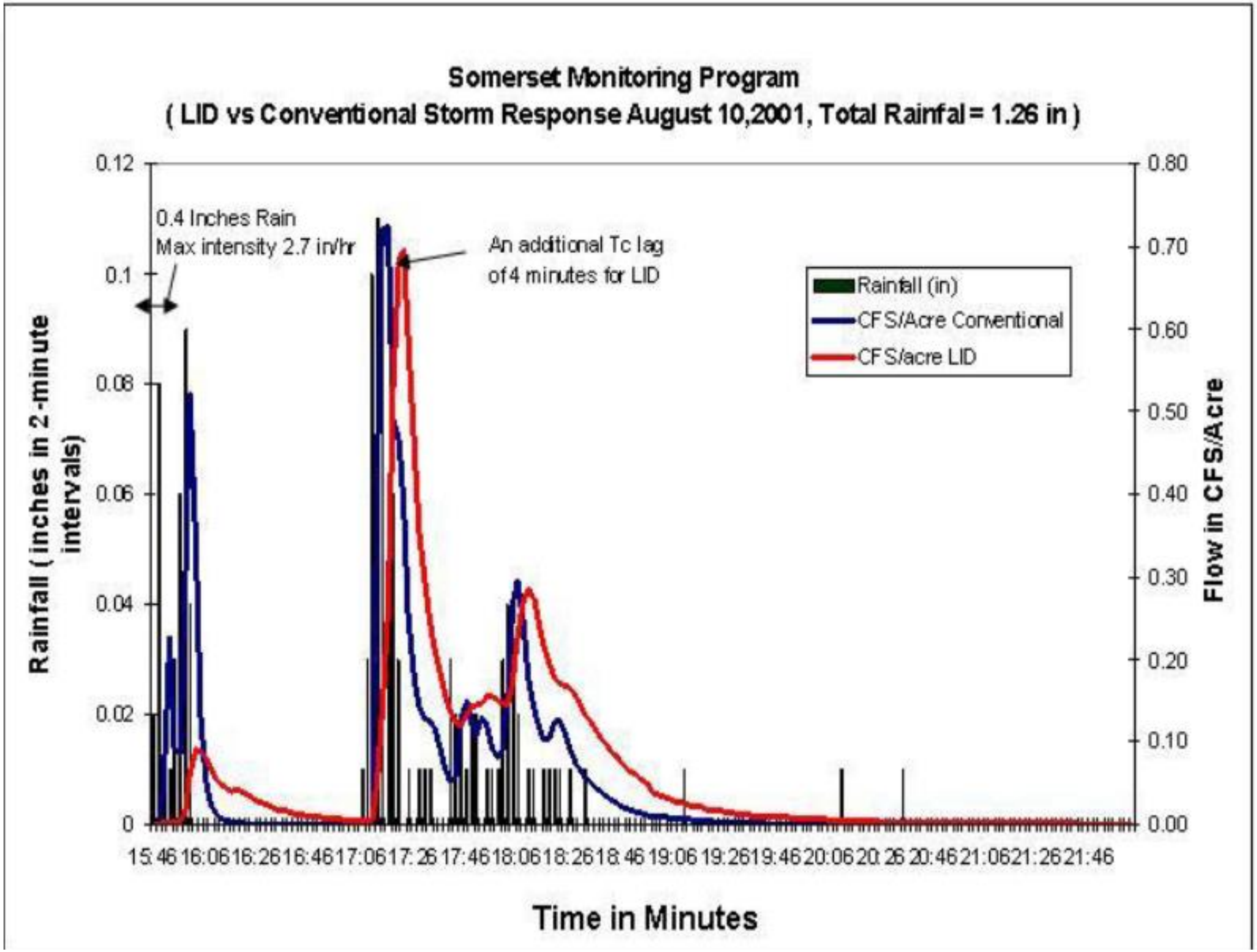
Somerset Monitoring Program

- Paired Watershed Monitoring Program Started in October 2000
- Comparison of Hydrologic Differences between Conventional and LID Stormwater Management
- 8.43 Acre Curb,Gutter and Pipe System
- 11.84 Acre Swale,Bioretention System

Conventional Development Site

Low-Impact Development site


Discharge Comparision
Discharge, cfs/acre
0.04
0.02
0.00
-0.02
13:55
14:24
14:52
15:21
15:50
16:19
LID Q
Conv. Q
Time, April 6, 2001



Somerset Monitoring Program
(LID vs Conventional Storm Response August 10,2001, Total Rainfal = 1.26 in)
0.4 Inches Rain
Max intensity 2.7 in/hr
An additional Tc lag
of 4 minutes for LID
Rainfall (in)
CFS/Acre Conventional
CFS/acre LID
Rainfall (inches in 2-minute intervals)
Flow in CFS/Acre
0.12
0.1
0.08
0.06
0.04
0.02
0
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
15:46 16:06 16:26 16:46 17:06 17:26 17:46 18:06 18:26 18:46 19:06 19:26 19:46 20:06 20:26 20:46 21:06 21:26 21:46
Time in Minutes

Gateway Projects (Green Highway Program)

- To improvement water quality by retrofitting the highway median and interchanges
- To demonstrate how LID techniques can treat stormwater pollutants generated by highway traffic

Green Highway Program

MD 202 (Largo Road) Green Highway Projects

Completed in January 2005

The First Green Highway/Street Project in the Washington Metropolitan Area

Sligo Creek
Green Street Program

Completed 2007

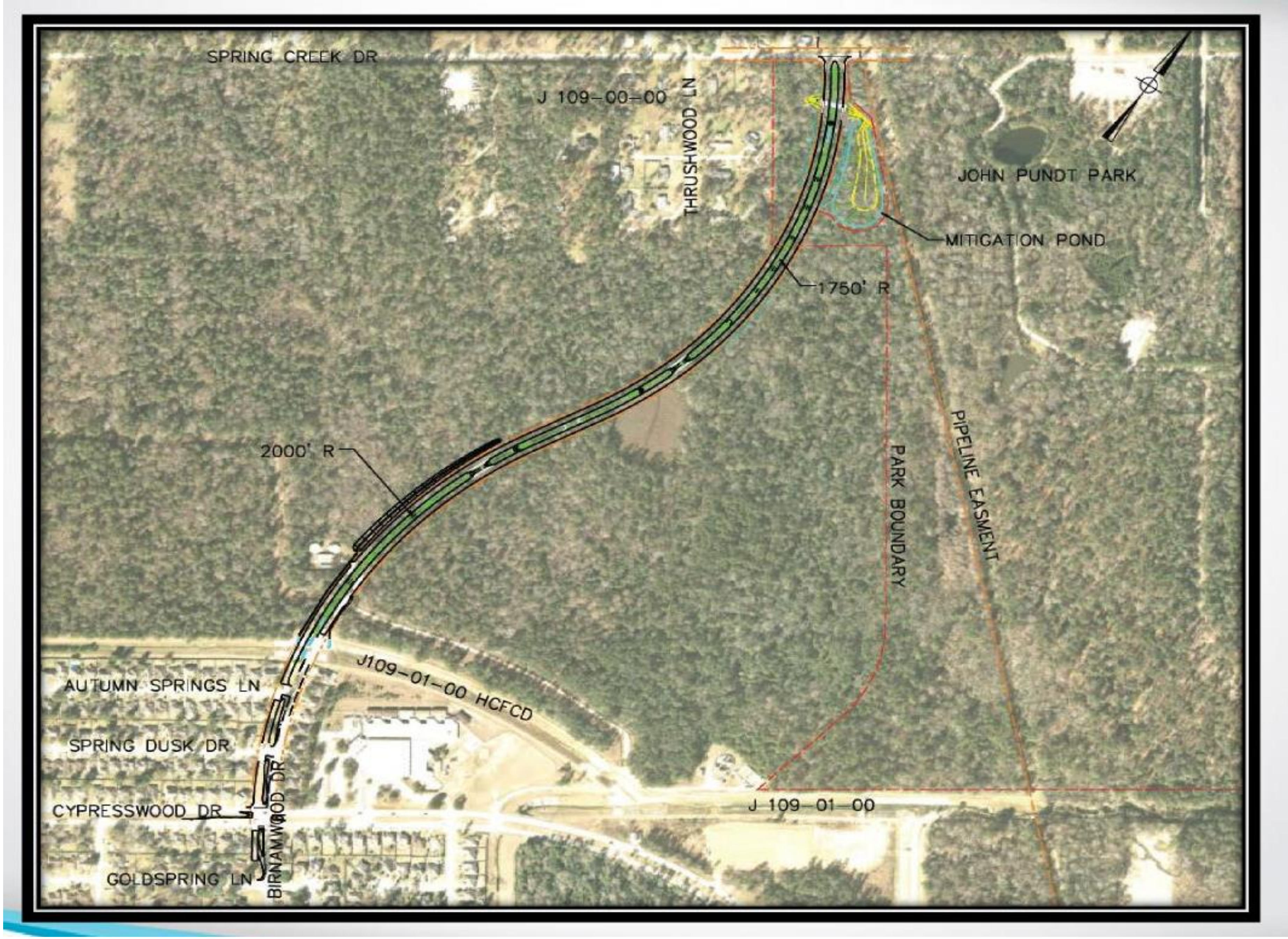
LID Urban retrofit projects

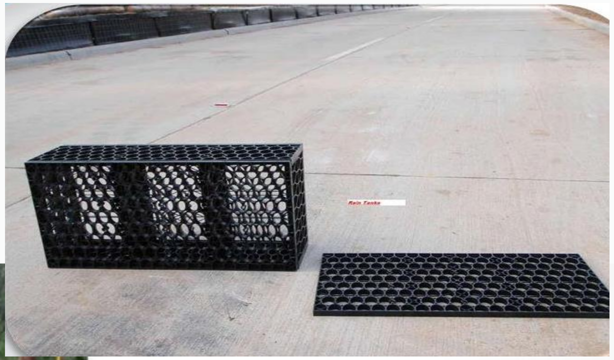
Before

After

University of Maryland LID Sites

BIRNAMWOOD DRIVE - LID CASE STUDY




Rain Tanks

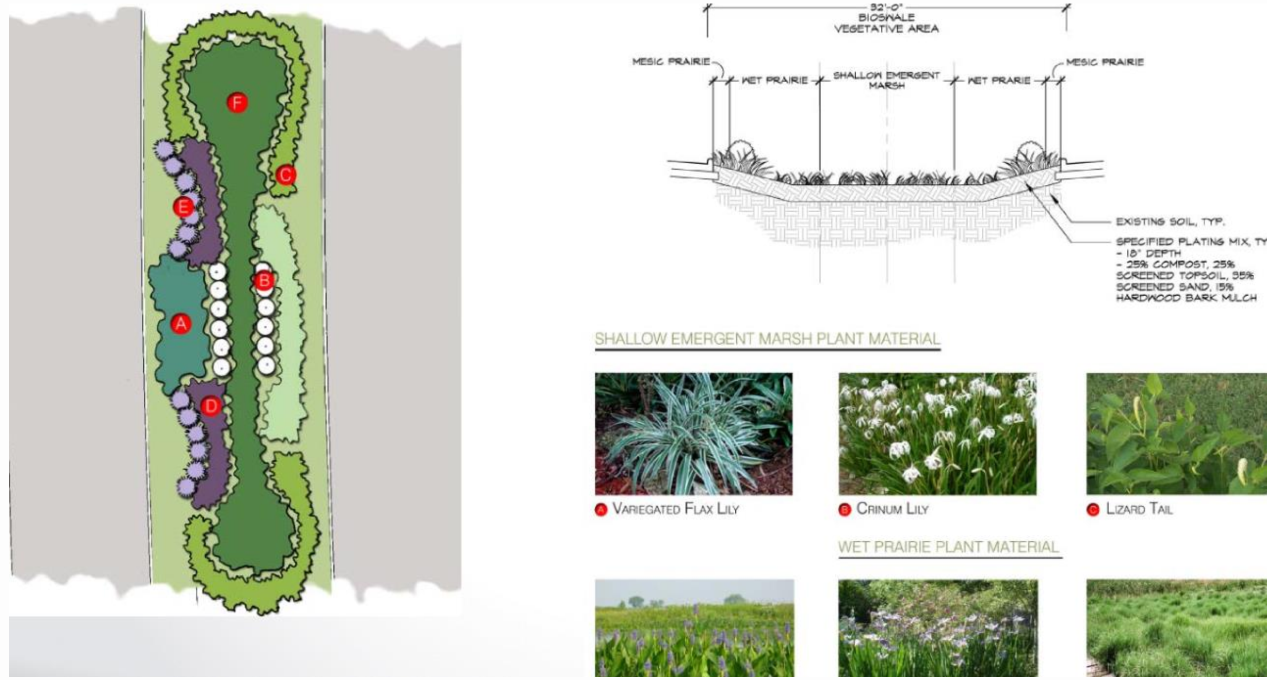

Geosynthetic grid

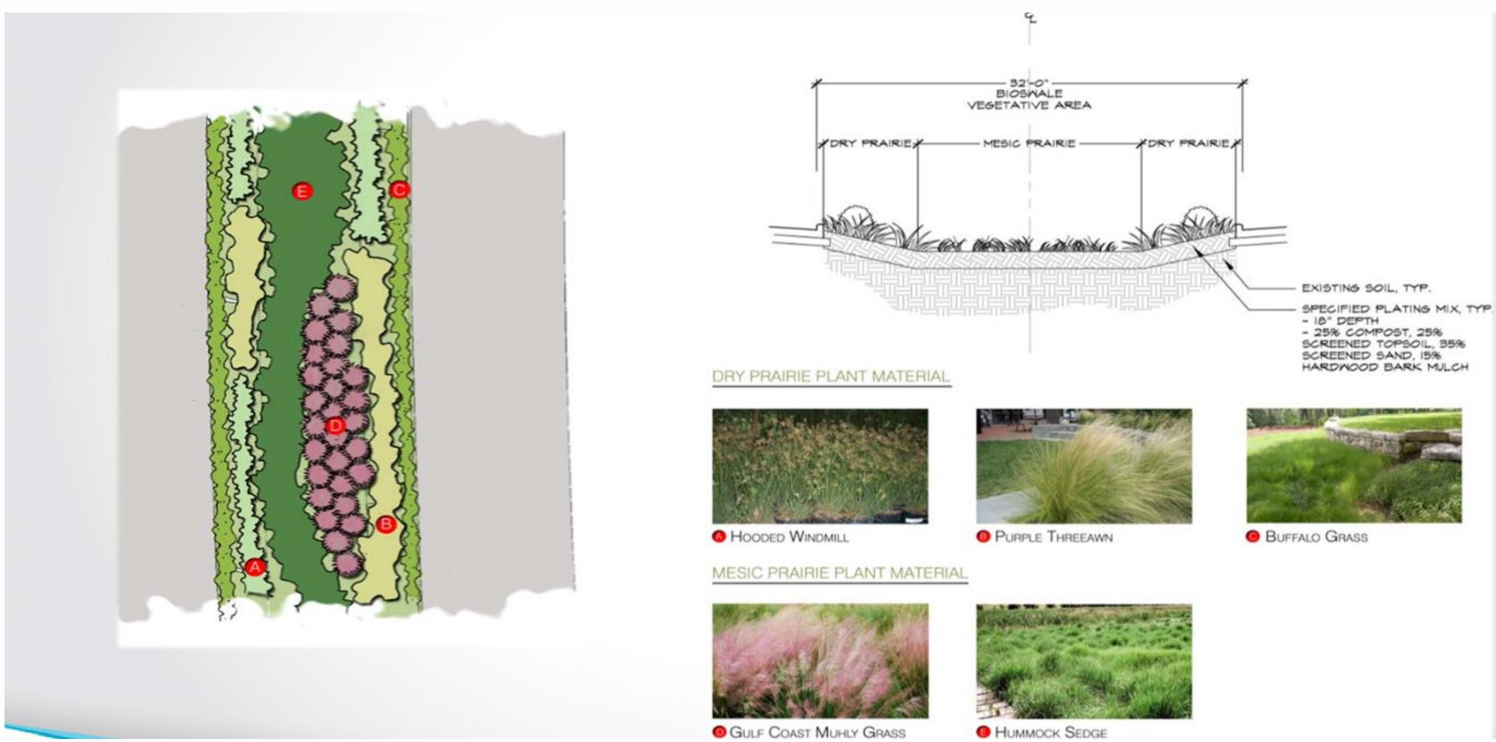
•RAIN TANKS


Installation of rain tanks
over geotextile fabric.

- ROCK BERM/DISSIPATER

- PLANT MATERIAL








Project completed

Gene Green Beltway 8 Park (in Houston)

Rain garden

Vegetated Swales

Detention

•Inlet Edge Filter

•Houston Land Water Sustainability Forum

Lakewood Crossing Park (in Houston) Project

LID Decision Support System （低衝擊開發的決策系統）

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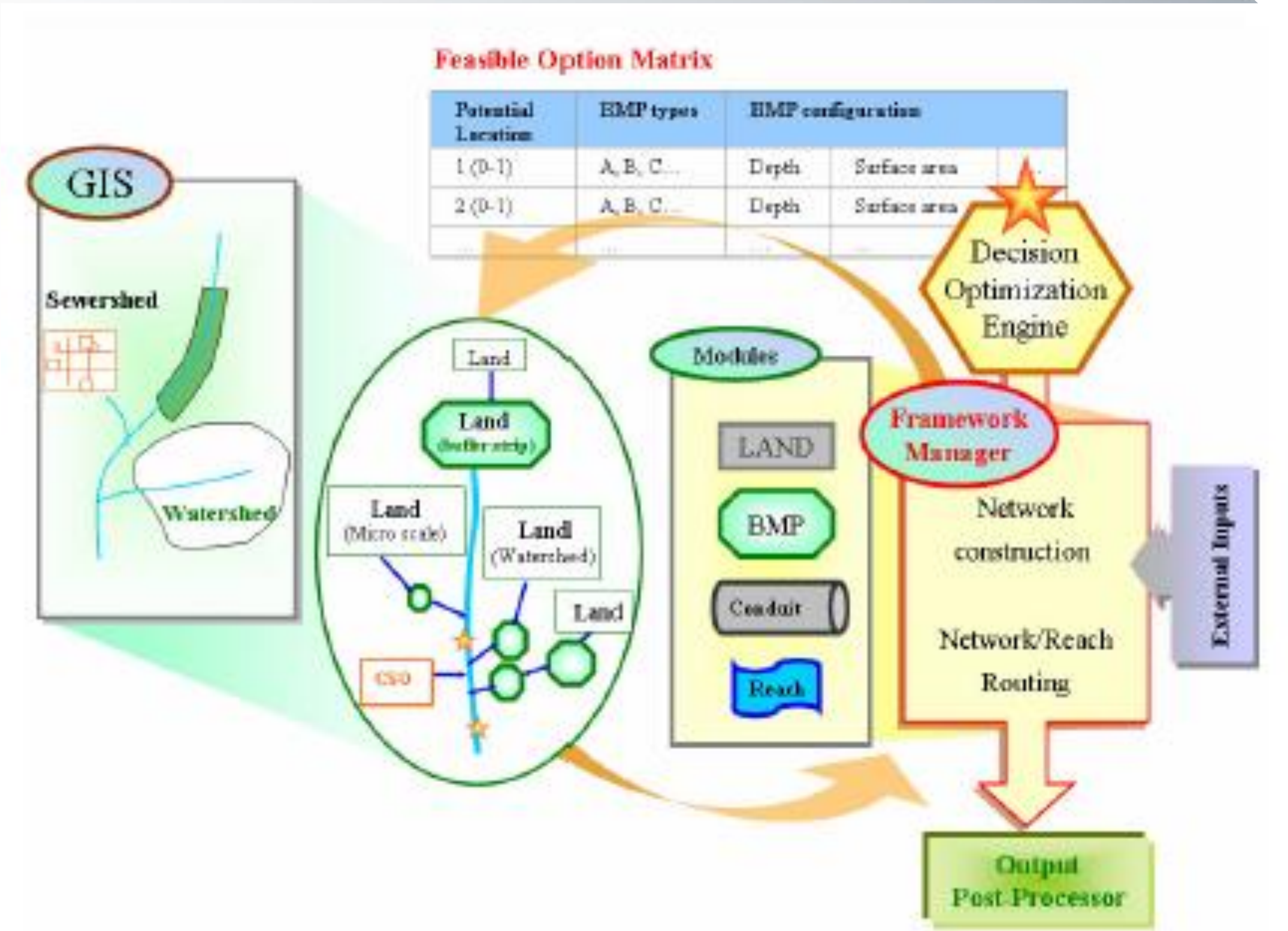
(Factors: Costs, Mitigation of Flood, Water Quality Control, Policies)

To assist the decision and planning for implementation of best LID practices through model simulation, data management and optimization.

EPA (SUSTAIN) - **System for Urban Stormwater Treatment and Analysis Integration** or other models

Support the selection and evaluation of viable BMP/LID options, and decide where these options are best placed in a watershed in a way that achieves cost-effectiveness in addressing environmental quality restoration and protection needs in urban and developing areas.

SUSTAIN


Feasible Option Matrix
Potential Location
BMP types
BMP configuration
1 (0-1)
A, B, C...
Depth
Surface area
2 (0-1)
A, B, C...
Depth
Surface area
GIS
Sewershed
Watershed
Land
Land
Land (Micro scale)
Land (Watershed)
Land
CSO
Modules
LAND
BMP
Conduit
Reach
Decision Optimization Engine
Framework Manager
Network construction
Network/Reach Routing
External Inputs
Output Post-Processor

LID Benefits

For Developer and Realtor

- LID can reduce the size and number of detention facilities and the size and cost of drainage infrastructure.
- Systems designed to mimic nature can enhance aesthetics and increase property values.
- Surface vegetative systems are more visible, thereby facilitating routine maintenance and requiring less maintenance than underground practices.

Example LID benefits to homeowners:

- Reduce the occurrence of flooding.
- Reduce the cooling costs.
- Increase attractiveness or value.
- Improve significantly the water quality.
- Reduce the payment of stormwater fees.

Example LID benefits to the community :

- Protecting natural ecosystems through LID practices provides benefits to communities such as: reduced flooding, improved water quality, increased groundwater recharge, improved air quality, enhanced aesthetics, enhanced property values, increased open space, and carbon sequestration.

- Protecting water quality through LID maintains the value of clean water, which is a quality of life benefit.

Example LID benefits to local governments:

- Protecting water quality.
- Reduced inflow.
- Reduced flooding.
- Reduced filtration costs.
- Conservation of water.
- Reduced public expenditures.
- Reduced regulatory costs associated with water-quality impacts.

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Conclusions

Low Impact Development (LID)

- A sustainable stormwater management through comprehensive land development (or re-development).
- It is a potential land development option to address drainage, flood control, and storm water quality requirements.
- Development works with nature to manage stormwater as a resource rather than a storm sewer.
- Use distributed micro-scale controls to mimic the site’s pre-project hydrology and to reduce the occurrence of flooding.

Conclusions (cont.)

- LID employs principles of "Green infrastructure“.
- Promotes the natural movement of water within an ecosystem or watershed.
- The green structure includes as bioretention facilities, rain gardens, vegetated rooftops, Vegetated Swale, Stormwater Planters, rain barrels, Tree Box, permeable pavements and water retention facilities.
- The low impact development technology must be integrated into the site planning process to achieve a successful and workable plan.
- LID has been adapted successfully to a range of land uses from high density ultra-urban settings to low density development.

References

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4. Lai , Fu-hsiung , Dai,Ting, Zhen, Jenny, John , Riverson, Alvi, Khalid, and Shoemaker, Leslie, "SUSTAIN - An EPA BMP Process and Placement Tool for Urban Watersheds", TMDL, 2007
5. Chang, C.C., Personal communication.
6. http://www.ces.ncsu.edu/depts/agecon/WECO/nemo/documents/WECO_LID_econ_factsheet.pdf.
7. Stormwater Conveyance Modeling and Design (Haestad Methods and S.R. Durrans).
8. CIVE4312 student reports.

Thank you.

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