ARIYA ARUNINTA

LANDSCAPE

ARCHITECTURAL DESIGN AND CONSTRUCTION TECHNOLOGY

Alpha Science

Landscape Architectural Design
and Construction Technology

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Ariya Aruninta

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There are so many kinds of books for me to read.
Some bring me joy;
Some give me knowledge and entertainment.
I therefore read every day.
Books present a diversity of subjects,
For readers to explore for their own pleasure.
Since there is so much that can be discovered in books,
I will continue reading for the rest of my life without getting bored.

—HRH Princess Maha Chakri Sirindhorn, composed when she was 12 years old

Translated by the Chalermprakiat Center of Translation and Interpretation, Faculty of Arts, Chulalongkorn University, as part of Chulalongkorn University Press's celebration of the 60th Birthday of HRH Princess Maha Chakri Sirindhorn

Preface

Landscape Architectural Design and Construction Technology was originally written to be used as a supplementary reading for Landscape Architectural Construction, an M.LA. course with 3 credits (1-4-6) s/u. It comprises a 1-credit lecture and 2-credit studio for students whose undergraduate major was not landscape architecture. This course aims to cover all of the content related to landscape architectural construction taught at undergraduate level. As for the former curriculum, landscape architectural construction is taught in LA Cons I (second year, second semester), LA Cons II (third year, first semester), LA Cons III (third year, second semester) LA Con IV (fourth year, first semester) while in the new curriculum, they are taught in LA Tech/Cons series. It can be said that there is actually no book about landscape architectural construction accompanying the undergraduate program. However, *Landscape Architectural Design and Construction Technology* can supplement LA Tech/Cons and LA Cons Tech of both undergraduate and graduate programs.

In addition, since the technology of landscape architecture has been changing from the concepts of the last century, this book can be used as a reference for a landscape architect as it contains illustrations and pictures taken both domestically and internationally with findings from research carried out by the writer who has been conducting research in this field and is a chartered landscape architect. This book can also be used as a foundation for developing a Thai textbook related to construction and design with the objective to help readers.

1) To understand the concept of design and necessary techniques for construction of Landscape Architecture that is necessary in this professional practise. Also to be used as a found action to enhance practical work in this field or help further studies.

2) To understand the concept and to be able to develop different design.

3) To understand the concept and be able to analysis and improve site condition.

4) To understand the concept and be able to select material in the construction of landscape architecture.

5) To understand the structure and be able to design preliminary systems that can be used for engineering.

The writer hopes Landscape Architecture Design and construction technology will be a stepping stone in helping Thai landscape architects become the best in this region and to be of use for students, landscape architect and others associated in the industry. The writer humbly accepts all comment and suggestions for future improvement.

Ariya Aruninta

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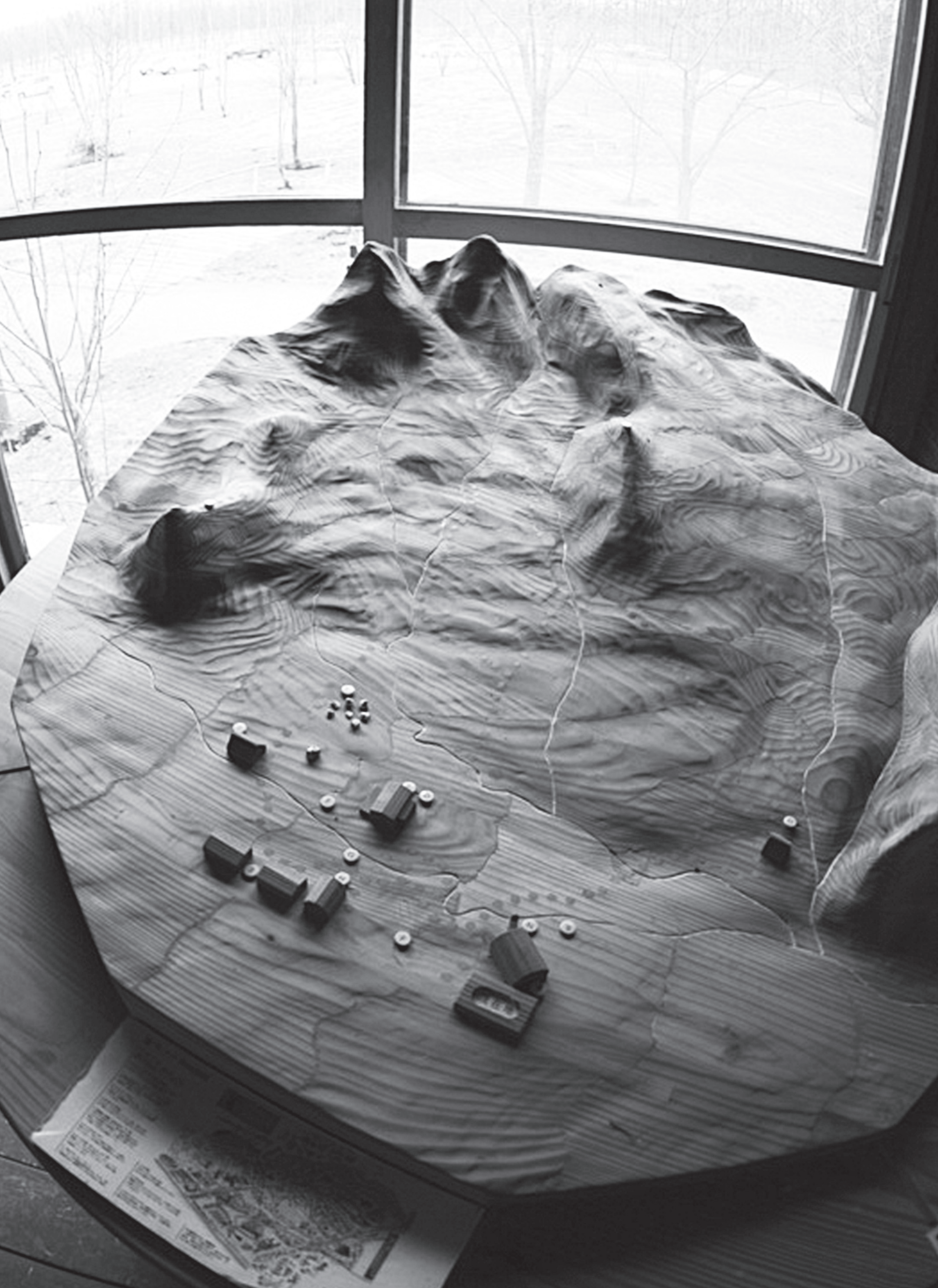


A roof made of a natural material – bamboo – by using a construction technique through which all the joints can be adjusted. This was the roof of the summer pavilion displayed in the 2005 World Expo in Aichi, Japan. This illustrates the importance of construction technology on landscape architectural design.

Chapter 1

Introduction

1.1 Preface

Design Studio and Construction are two separate courses in the landscape architecture curriculum; however, in practice they cannot be separated since to construct a structure, one has to integrate its design in the construction plan. A good design means the integration of appropriate construction techniques and the existing related knowledge and technology. The landscape architecture reflects its concepts and construction of that time. The writer, therefore, explains these concepts by comparing projects of different periods. *Landscape Architectural Design and Construction Technology* focuses on the analysis of design ideas related to landscape architecture and construction behind such projects so that the readers can apply them to their work.

1.2 Relationship between design and construction

Some projects are illustrated along with explanations about their design concepts and their construction techniques. This chapter explains the characteristics of an appropriate design that integrates suitable construction technology and the factors that indicate such characteristics so that they can be used as references for future designs.

Figure 1.1 *The arched entrance of the 2005 World Expo in Aichi, Japan. As the entrance was an open area, a roof was required but there had to be so few posts that they would not obstruct the flow of visitors. The architect used an arched roof made of iron trusses iron that could cover a large area but required few posts located at certain intervals.*

Various buildings in Japan exemplify the appropriate integration of design and construction techniques and they can be used to differentiate what is not appropriate integration. The appropriate integration of design and construction techniques should reflect:

Figure 1.2 *Summer pavilions with different kinds of roofs displayed in the 2005 World Expo in Aichi, Japan. These beautiful roofs were uniquely designed and built with modern techniques and materials. They were in line with the theme of the event – Natural Wisdom. The unique characteristics of these roofs were the design of joints and the binding of materials such as the stretching of canvas and the binding of circular–cut posts together with specially designed joints so that they could be adjusted into different shapes.*

1.2.1 The balance of construction techniques that signify sustainability.

Fifty years ago, science and technology stressed the importance of synthesis – creating natural substitutes and this resulted in many environmental problems, in particular, climate changes. Consequently, environmentally-friendly products have emerged. In terms of architecture, fifty years ago, industrial development was the focal point; as a result, construction materials were concrete and iron and the interior design relied on air conditioning. One might ask how construction materials such as concrete and iron can harm the environment or adversely affect the climate. I would like to provide reasons by talking about greenhouse gases which trap toxic gases like carbon dioxide. The manufacturing processes of iron and cement release more carbon dioxide than those of other construction materials. The ratio is concrete 4 : iron 3 : wood 2 metric ton per 100-square feet of a single-story building. Plus, Building Construction coupled with urbanization lead to deforestation, the disappearance of green areas and more impervious surfaces.

Figure 1.3 *Ant's nest and communication appliances. This playground is designed by Takano Landscape and houses playground equipment on which children can use their imagination while playing without the help of electricity or electronic devices. The clerestories in each room are painted with different colors, creating various feelings and uneven texture create shades and shadows, inspiring children's imagination. Moreover, there are tubes through which a sender can communicate from one end of the tube to the receiver at the other end.*

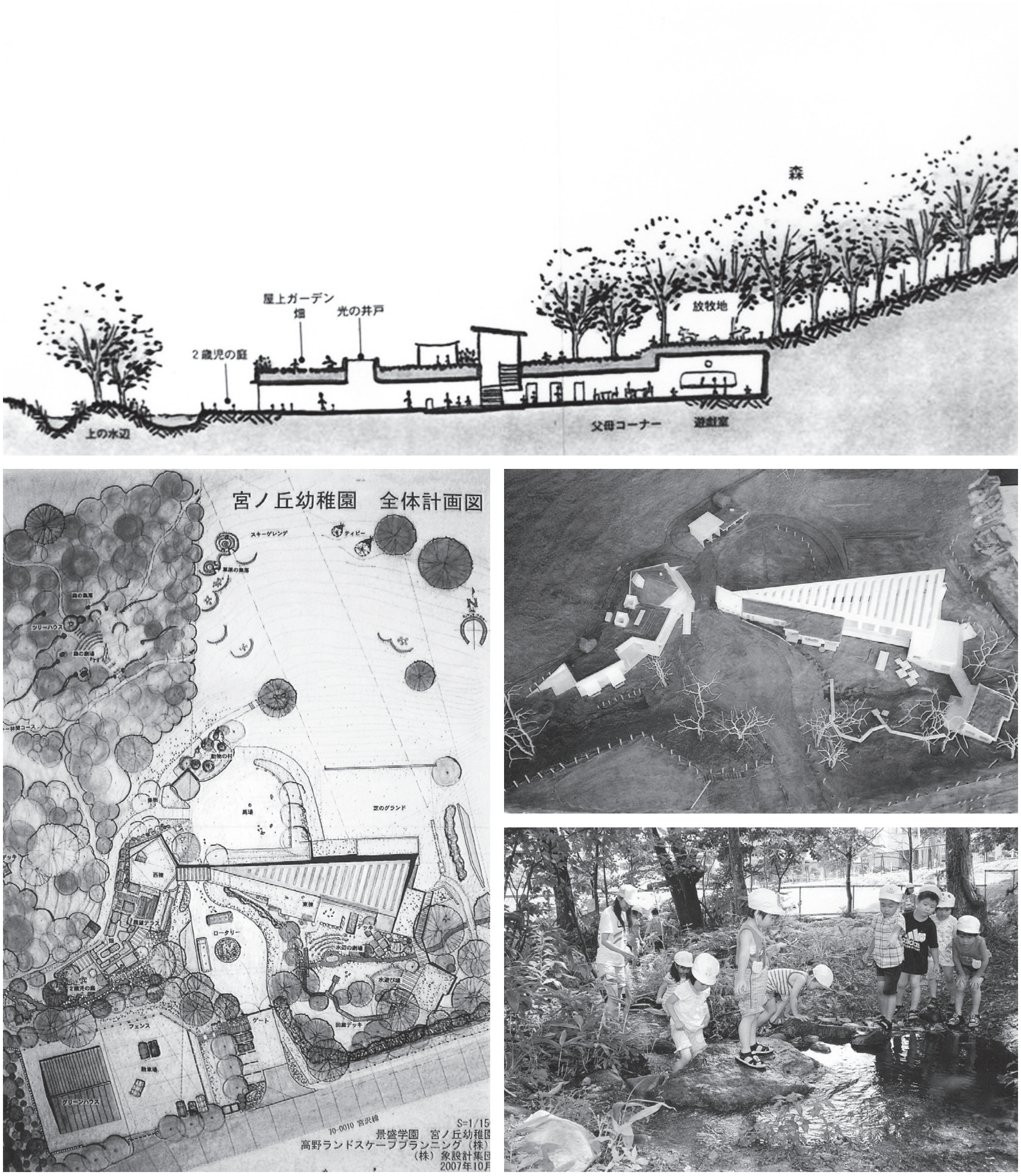


Figure 1.4 *Miyanooka Youchienn kindergarten (designed by Takano Landscape). This is respectful of nature because the school buildings are in the ground, getting rid of impervious surface so most rain water can seep through the ground. The architect made use of the elements of the site such as open swale running through the site. They serve as a case study of the ecology outside the classroom. The original grove wood behind the school is used as a recreation area for students.*

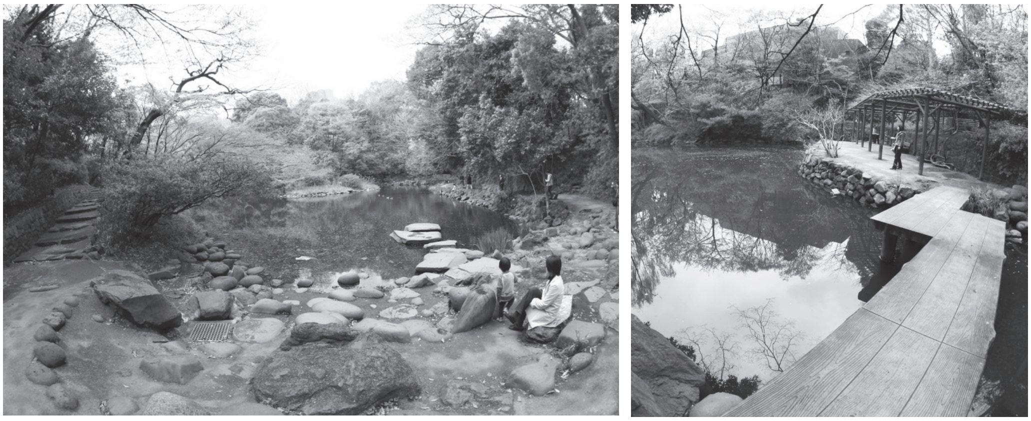


Figure 1.5 *Ikutokuen Garden and Sanshiro Pond, The University of Tokyo. These are pleasantly serene sites created according to the concept of "urban forestry" and provide a permeable surface. Although the university is in Tokyo, which is densely populated and brimming with activity, it is designed to reduce the hard and impervious surface by adding a pervious surface, another green area. In this case, it is Ikytokuen Garden and Sanshiro Pond.*

Figure 1.6 *Takahachi Construction Headquarters (designed by Takano Landscape). Besides the green roof, the company is designed to be part of the surroundings by creating a friendly atmosphere and breaking away from a box-like office. The company also relies on natural light and cools itself with the variety of plants.*

The recent construction design concepts are based on Three Zeros/ Target Zeros – zero carbon emission, zero water use and zero waste – for better environment and sustainability. The UK Green Building Council has added another aspect to make a building green and sustainable – zero energy.

1.2.2 A humble dialogue with nature.

Landscape architectural design that takes the nature of the site into consideration will not be costly both in construction and maintenance. The nature of the site includes wind, sunlight, shade, water and sound – and all of these are used to replace the air-conditioner, the artificial light and the amplifier. However, a thorough study of the site, sunlight, wind, hydrology and climate has to be carried out first.

Figure 1.7 *Millennium Forest – Ecology park. This is another work designed by Takano Landscape focusing on deleting/eliminating away the excessive elements. The natural site is intensified with a little touch of man–made design.*

1.3 Examples of design based on landscape architectural construction technology

It can be said that in the past some designs had materials that could harm the natural surroundings. Take the drainage system as an example in the past, to protect a site from flooding, the excess water would be drained off to the nearest public drainage system. However, at present, it is believed that water detention in the site is a better solution to reduce the burden of surrounding water-catchment areas at the micro and macro level. The following are examples of landscape architectural design concepts in the past and their construction techniques are also explained.

1.3.1 Designing a campus based on ecology-related concepts

The Asian Institute of Technology (AIT) was built using a ditch and dike system and a water detention area instead of filling in the area, while the Heriot-Watt Ricarton Campus was built in harmony with its low-lying area (Figure 1.9). The University of Bath is another example of this concept. The aerial photographs of Thammasat University and AIT (Figures 1.8) illustrate the planning of these two adjacent universities. The area of AIT was part of Thammasat University, which was earlier developed into a campus. According to the photographs, it can be seen that the planning and the land improvement of AIT make its site ideal for trees since the site is lower than the road, it contains more water than its adjacent area that is filled in so it can therefore be at the same level as the road. Instead the ditch and dike and water detention methods are used at AIT to protect the site from floods and to drain the runoff. The site of Thammasat University was also lower than the road surface but it was filled in, resulting in poor soil for vegetation. In addition to the high cost of land filling, the estimates for the drainage system and other landscape designs were high. As a result, the initial site improvement cost at Thammasat University was higher than at AIT.

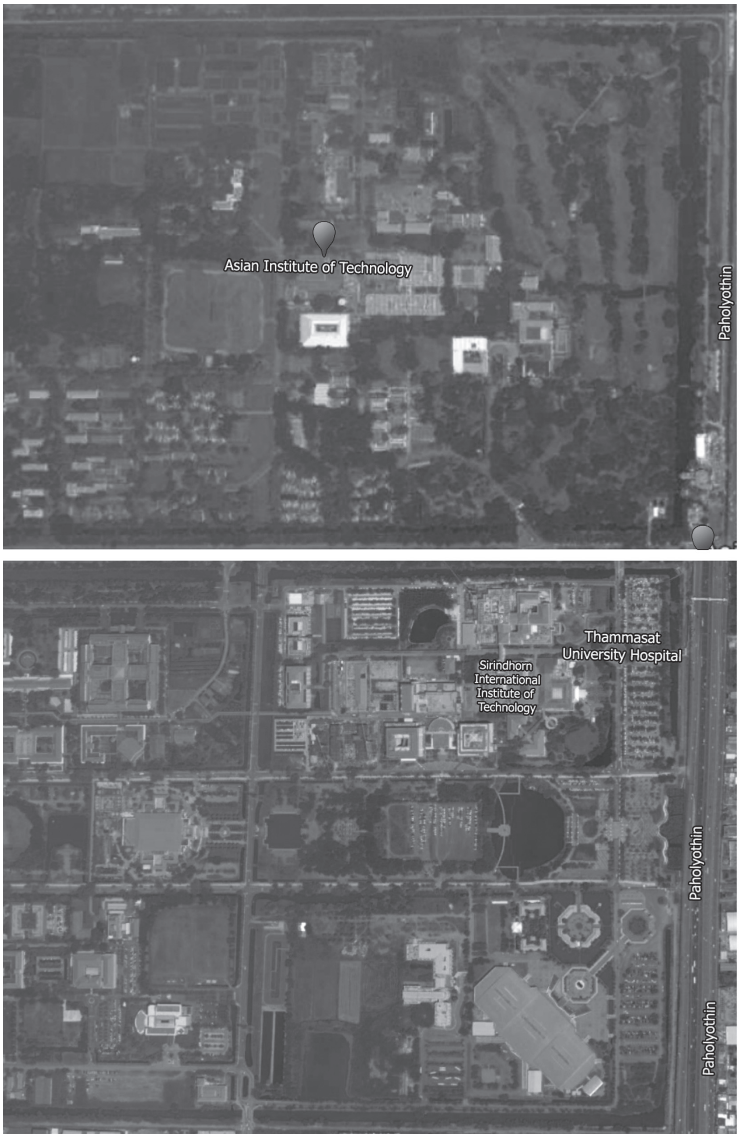


Figure 1.8 *The aerial photograph of AIT (left) and that of Thammasat University (right). It can be seen that the area and the vegetation in these two areas are clearly differentiated due to different ideas of site improvement and flood prevention methods.*

1.3.2 Designing river bank areas based on flood plains

With this design, the area can be used for other purposes during the dry season and as a water basin during the rainy season. Such a design can be found along the Seine River in Paris, France, York River in England and the land

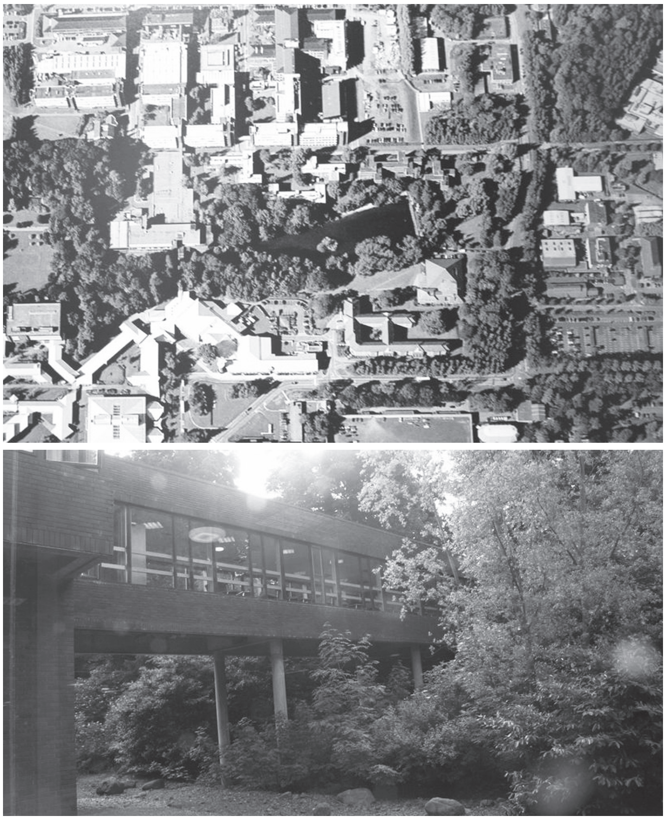


Figure 1.9 *Heriot-Watt Ricarton Campus, Edinburgh. Its purpose is to disturb the site the least. The buildings are compact so there is a lot of green space. Moreover, both the buildings and the corridors are raised above ground so there is no impervious surface.*

developments by the river in Seoul (Figure 1.10). This idea has not yet been introduced in Thailand. The levee in Thailand is built at a right angle to the water level. The height of the levee is the same as that of the water when it rises to the highest point. This results in an eye sore and poor accessibility to water such as in Loy Kratong event. Water cannot be readily accessible. A step ladder or a big platform has to be built so that such activities can be organized. Furthermore, this structure also forces water to follow a narrow long channel so the massive volume of water will accumulate along the way to the end of the channel. This makes the water level at the end of the channel much higher.

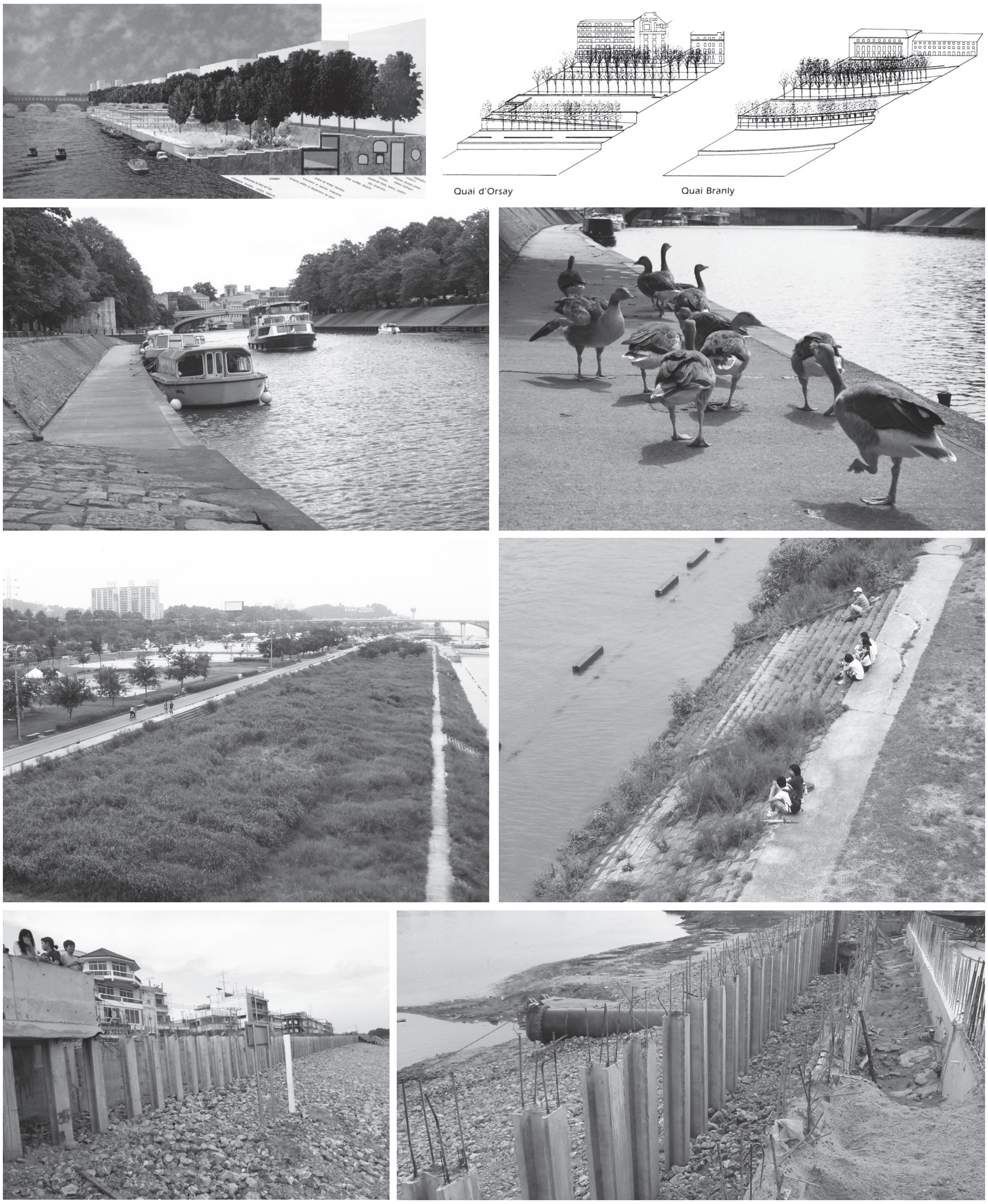


Figure 1.10 *Designing the river bank area based on flood plains. The area serves as a functional area alternating according to the season. Such areas are found near the Seine River in Paris, France (first row), York River in England (second row) and the land developments along river in Seoul, South Korea (third row). When compared with the levee wall along the Chao Phraya River in Nakon Sawan Province, it can be seen that the ridge of the levee is very high so it is difficult to be accessed.*

Figure 1.11 *The gabion box at the parliament building, Scotland.*

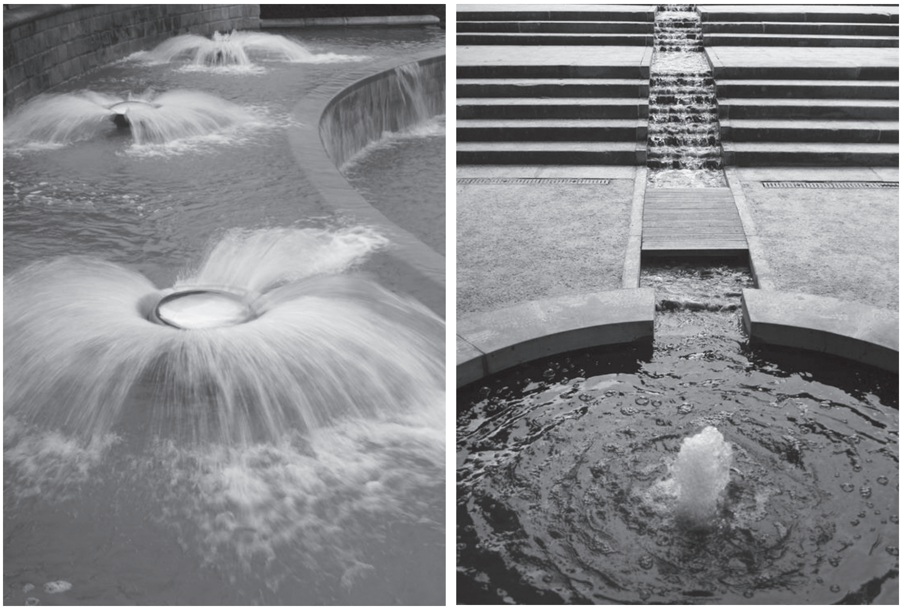


Figure 1.12 *The water garden in Alnwick Castle. Different kinds of fountain are used to create different atmospheres.*

1.3.3 Designing an embankment

This design allows people to reach the bank area more easily but still maintains its natural setting. The gabion box or gabion mattress is used along the river bank area to protect from soil erosion. Sand bags filled with cement can also be used for this purpose. They can replace rip rap or rockfill dams because they are cheaper than rocks and easier to transport. The Parliament building in Scotland designed by the Catalan Architect Enric Miralles forms an organic structure because it is designed in line with its site, a rocky hill (Figure 1.11).

1.3.4 Using various kinds of fountains to create a cozy atmosphere

The use of a fountain is a science and an art in that the architect has to have an insight into the nature of water, sunlight wind direction of the site, the water system of the fountain and the type of fountain. In addition, he has to be creative to combine a fountain into the site in an interesting way. Examples are the garden of Alnwick Castle, which offers different kinds of fountain such as fountains accompanied with music, streams and waterfalls scattered around the garden. Visitors can hear water dropping, flowing and gushing alternately while strolling in the garden. The effects of water can be used in different ways – as part of landscape architectural design (Figure 1.12).

Another example is incorporating fountains into the designing of monuments. Princess Diana's Memorial designed by Kathryn Gustafson and Neil Porter is an example of this concept. Different fountain nozzles are used to represent different periods of Princess Diana's life (Figure 1.13). The fountains used in Queen Suriyothai's Memorial Park represent the enemies and the different water levels, water representing advancement during the dry season and the retreat during the rainy season of the enemies. They depict what happens in a battlefield (Figure 1.14).

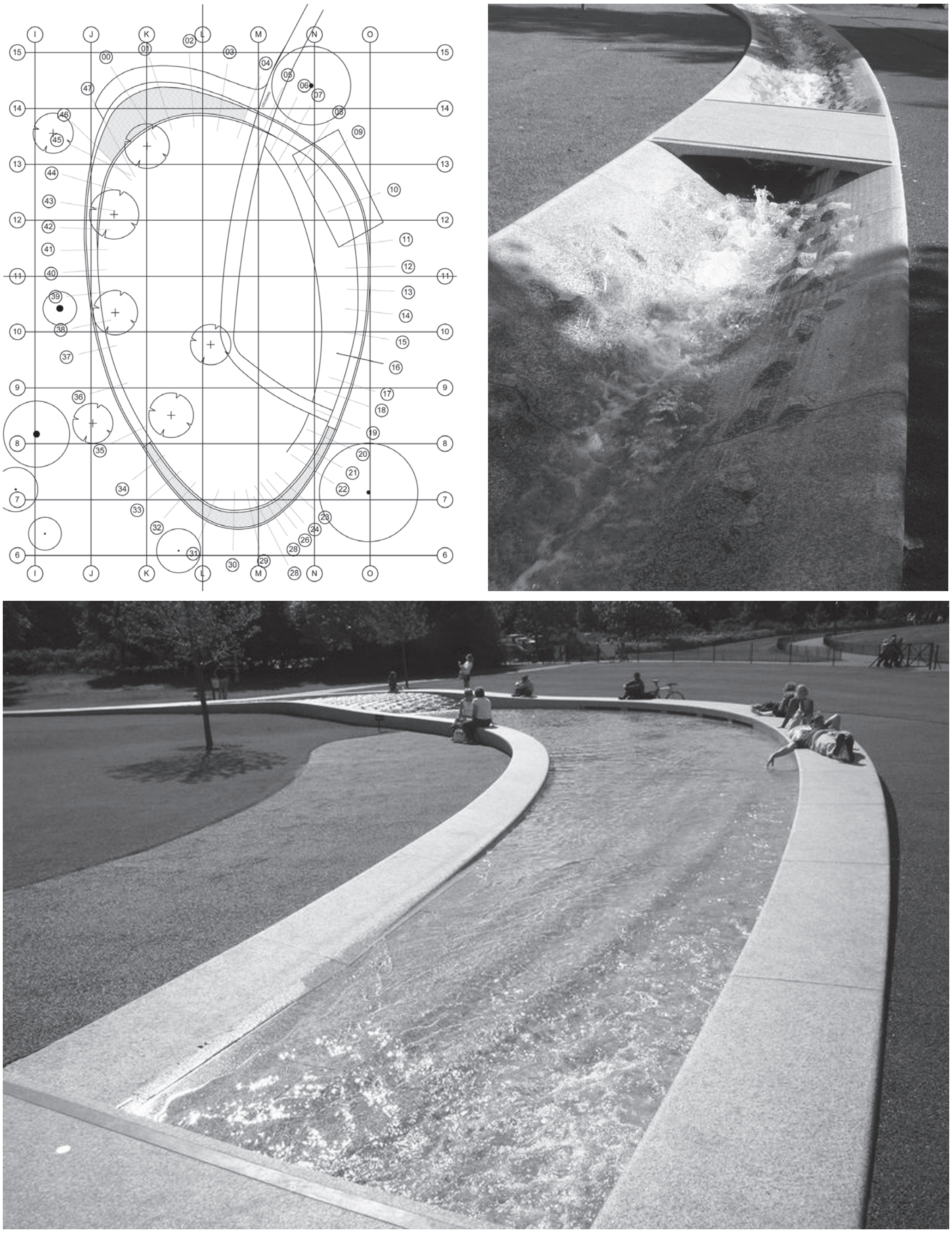


Figure 1.13 *The heart-shaped plan of Princess Diana's Memorial surrounded by different types of water effects (left). Different fountain nozzles represent different periods of her life (middle, right). Kathryn Gustafson and Neil Porter were the landscape architects.*

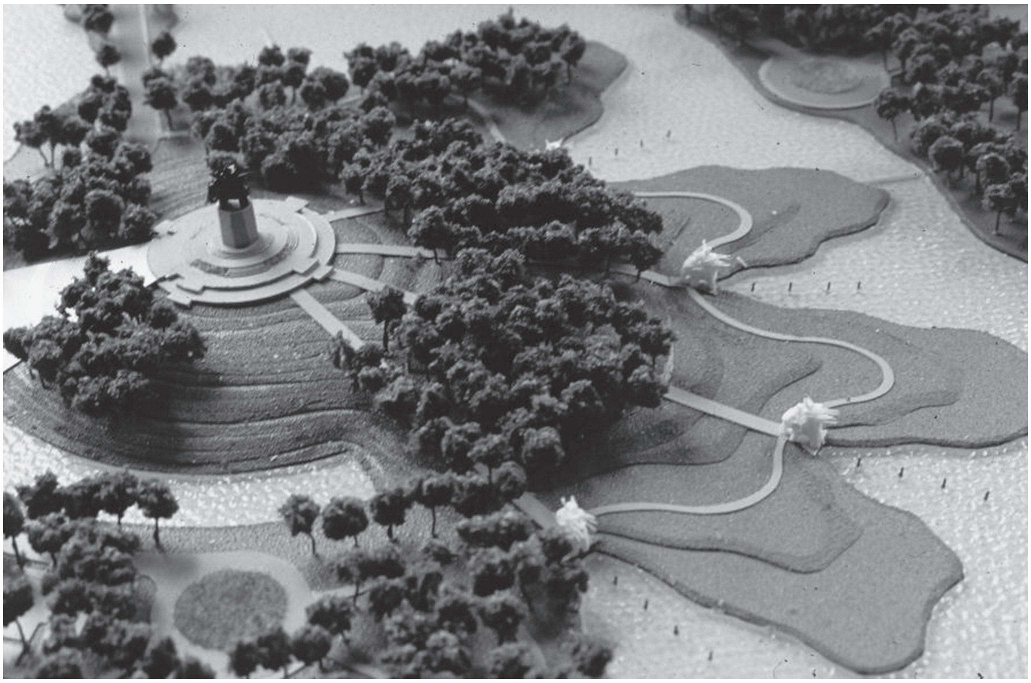


Figure 1.14 *The model of Queen Suriyothai's Memorial Park. Different levels water represent the movement of water during each season (above) and the fountains also represent the four enemy armies that surrounded Ayuttaya (bottom). The monument is designed by Ariya Aruninta, landscape architect at the Department of Public Works and Town & Country Planning.*

Chapter 2

Contour Line

2.1 Preface

To improve the site so that it can be higher, lower, flatter or steeper is both a science and an art in landscape architecture, in that, the site has to be beautifully designed, facilitate water flow and be effectively functional. Without improvement, the site can cause technical problems; for example, it might be too steep to commute or too rough to be used as a sport ground. A landscape architect has to consider the aesthetics, drainage and function when grading the site.

There are many projects that are distinctive in terms of site improvement. Some of these projects illustrated in a book titled *Inspired by Earthworks and Beyond* (Beardsley, J.) are those of Michael Heizer, Robert Smithson, Walter De Maria, and Robert Morris. Some of these depict spiritual

Figure 2.1 *Outdoor amphi theatre on a river in the University of Bath, UK. The stage is modified according to the existing topography.*

Figure 2.2 *Bronze sculptures are placed at different levels in Ishiyama Stone Park, Hokkaido. Compare the before Figure and the after. This quarry is converted into an outdoor art gallery, equipped with benches, mound, steps and slopes. It provides a panoramic view of the surrounding hills.*

meaning, some are open-air sculptures, and some are part of the surroundings or public areas. Turning the area into a small hill can be considered an art and can have a symbolic meaning. Either higher ground like a moat for a monument or lower ground like a sunken theatre, which can create certain meaning.

Engineering knowledge can play a part in this site improvement because the stability of the ground and the geological features of the area have to be taken into consideration. In addition, vegetation has to be planted to hold the soil or protect soil erosion in addition to making the site more beautiful. The curve and the bend also have different light effects at different times of the day. Reclaiming such areas as old mines or landfill shas to take the above aspects into consideration. Site improvement is essential for a golf course because it has to be a challenge for golfers and be equipped with a good drainage system and suitable vegetation. One example is the Pebble Beach Golf Course, Monterey, California.

An accurate estimation of earth work for site improvement can reduce the project cost on filling in the site or taking the earth out of the site. A suitable site improvement plan can also save the existing vegetation, while an unsuitable one can turn a fertile area into an infertile area and the vegetation will not grow as it should. Take the AIT site and the Thammasat University site in Chapter 1 as examples.

Turning the site into a retention pond and a detention area requires knowledge about site improvement and drainage system. At certain times, this area cannot serve certain activities because of floods but the site will not be damaged by such floods. Site improvement leads to attractive sights as well. At the monumental scale, take for example: Michael Heizer's works - Isolated Mass/Circulflex No. 9, The Nine Nevada Depressions (1968), Robert Smithson's works – Spiral Jetty, Great Salt Lake, Utah, Estate of Robert Smithson (1970), Amarillo Ramp, Amarillo, Texas (1973) and Broken Circle and on the Slope Above, Spiral Hill, Emmen, Holland (1971) and Isamu Noguchi's works – Play

Mountain (1933), and UNESCO gardens, UNESCO Building, Paris (1956-1958) show site improvement by turning flat areas into tourist attractions.

All in all, factors that should be taken into consideration when planning site improvements are the drainage system, function of the site, aesthetics. No matter what the purpose of the design is – to create a certain atmosphere, to signify a symbolic meaning, to be an art work or to create a certain feeling – all of the above factors are key for site improvement.

2.2 Landscape architectural design and landform

To design a building, an architect has to draw a plan for each floor, showing the height, the dimension of the building but a landscape architect has to present information about the location of the site and its geographical conditions both above and under the ground including elevation, slope, directions of water flow and the highest flood watermark. All information is presented in the contour plan and when there are some adjustments such as elevation or drainage system, the new information will be presented in the grading plan. In general, the contour plan and the grading plan can contain all the information needed for construction work on one piece of paper.

In the contour plan and the grading plan, the contour points and the elevation points of the same coordinates are connected together in a plan that contains both the existing contours and the proposed contours. The size of the area to be graded and the adjusted volume of dirt can be calculated based on the information in the plans. The contour interval has to be constant either upwards or downwards. The line that divides the major contour intervals is called the index. Sometimes the contour lines cannot be drawn because the area is too steep, so only the standardized index with elevation is drawn. The elevation and the slope of that area can, therefore, be estimated.

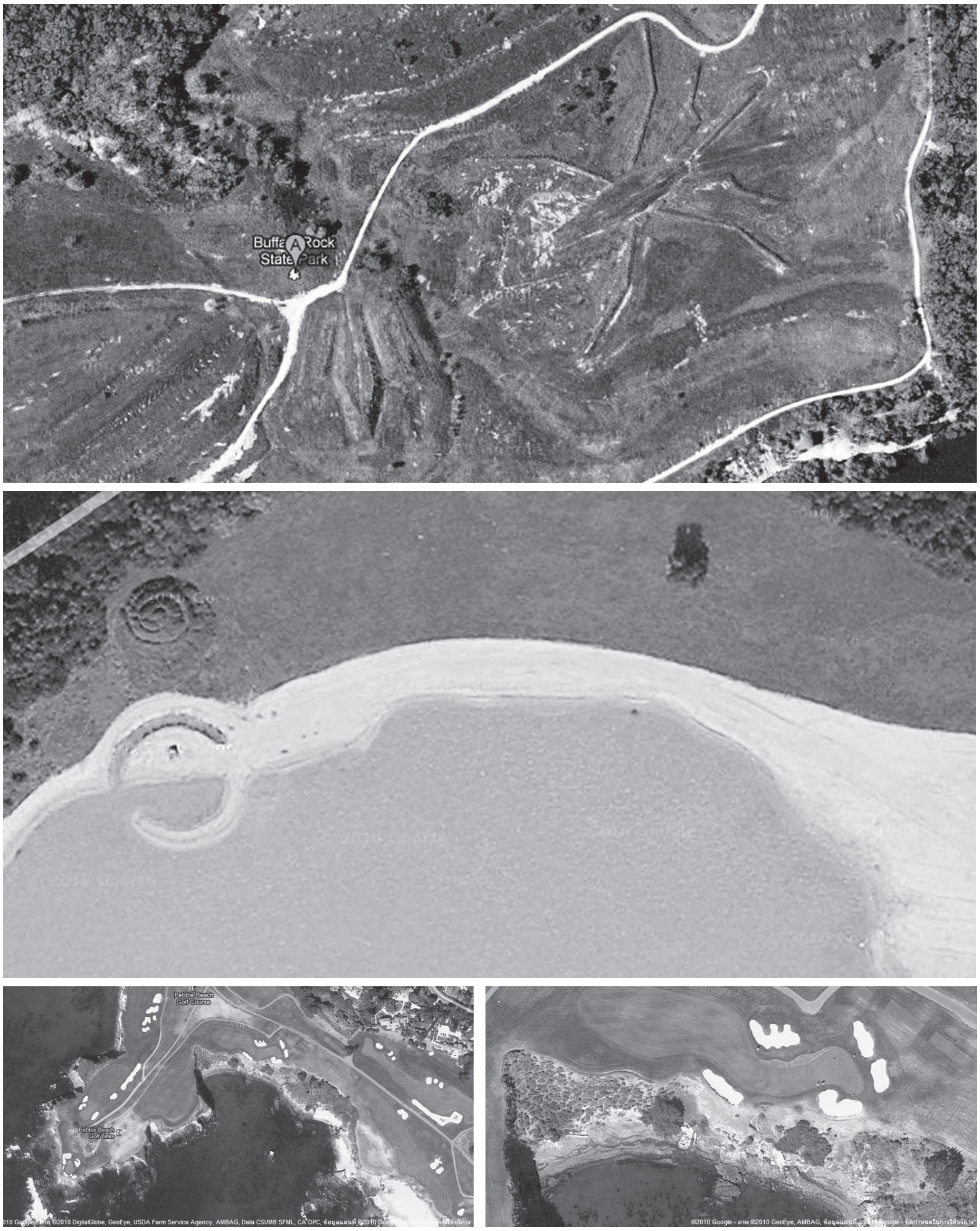


Figure 2.3 *The aerial photographs of projects that apply contour grading.*
Top – The Effigy Tumuli Sculptures, Buffalo Rock, Illinois.
Middle – Spiral Hill, Emmen, Holland.
Bottom – The Pebble Beach Golf Course.

Numbers will be assigned for each contour line. However, in the same project, the same method should be used. There are three ways to assign numbers.

- Above the line. This is the most popular method.
- On the line. Space is left evenly so the numbers can be seen easily.
- Above the line. The numbers are written as if they are 'walking' up the hill. The highest value number is always on the top part. This method is not popular because it is difficult to interpret.

The cross section and profiles can be used to better display the shape of the site because the contour plan shows the scale of contour lines at the horizontal level while the elevation can be interpreted from the cross section points of contour lines or the assigned spot elevations. The shape of the hill or the valley, whether it is pointed or rather round, cannot be represented solely by contour lines and spot elevation. The cross section and profiles are used to illustrate the landform of the proposed contours. In addition, the profiles can help the engineer to estimate the volume of earth to be dug out or to be filled, judging from the squares between the broken lines (the existing contours) and the solid line (the proposed contours).

As for civil engineering, the cross section and profiles show the clear features and directions of slopes. The scale of the horizontal level is different from that of the vertical level; however, this might cause confusion during construction so the scales for both levels should be clearly specified.

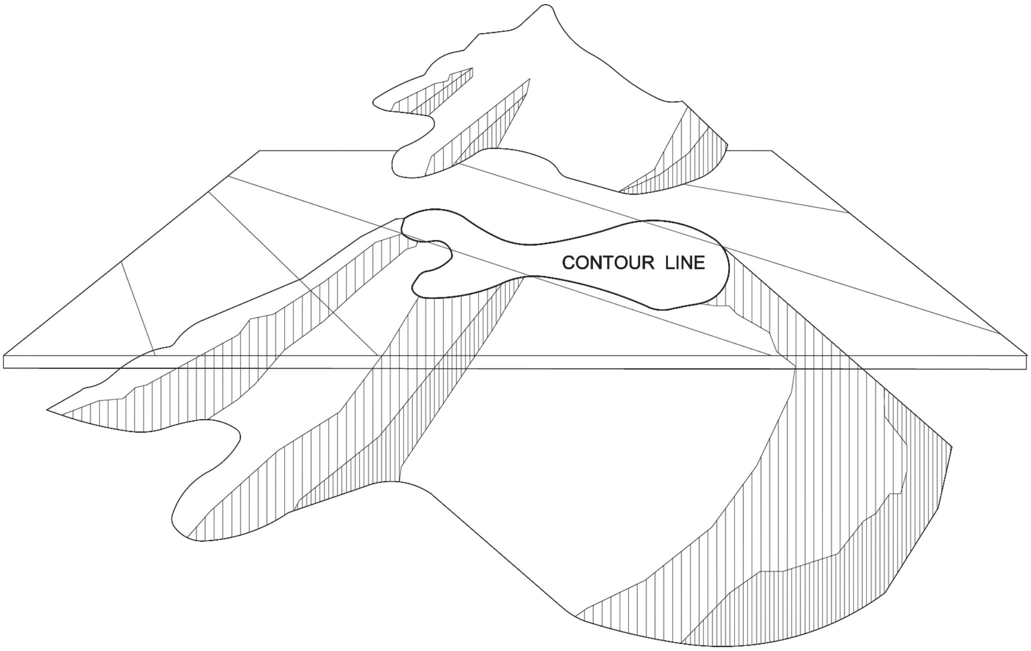


Figure 2.4 A model showing contour lines that look like cut glass panes. Each layer has the same height and the same distance such as every 0.05 m., 1.00 m., 2 m., and 5 m.

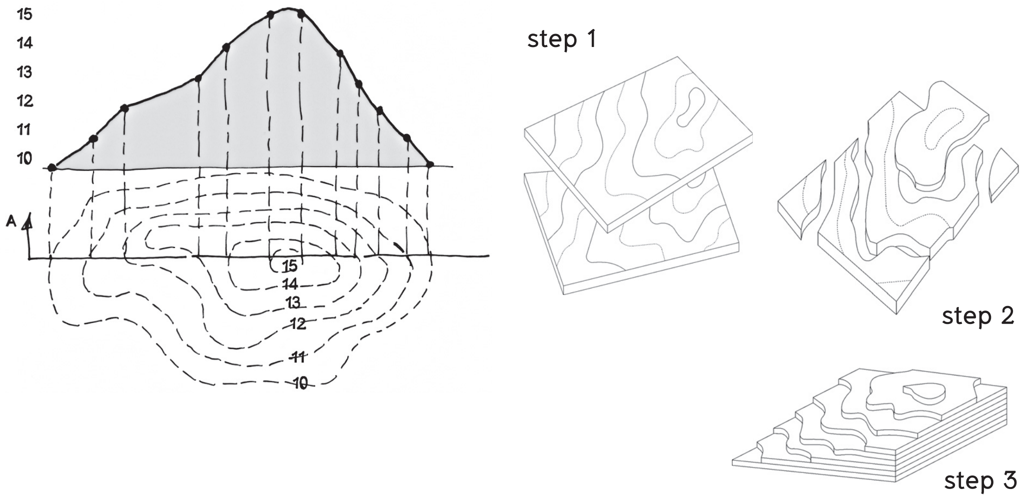


Figure 2.5 The profile and the hollow core model

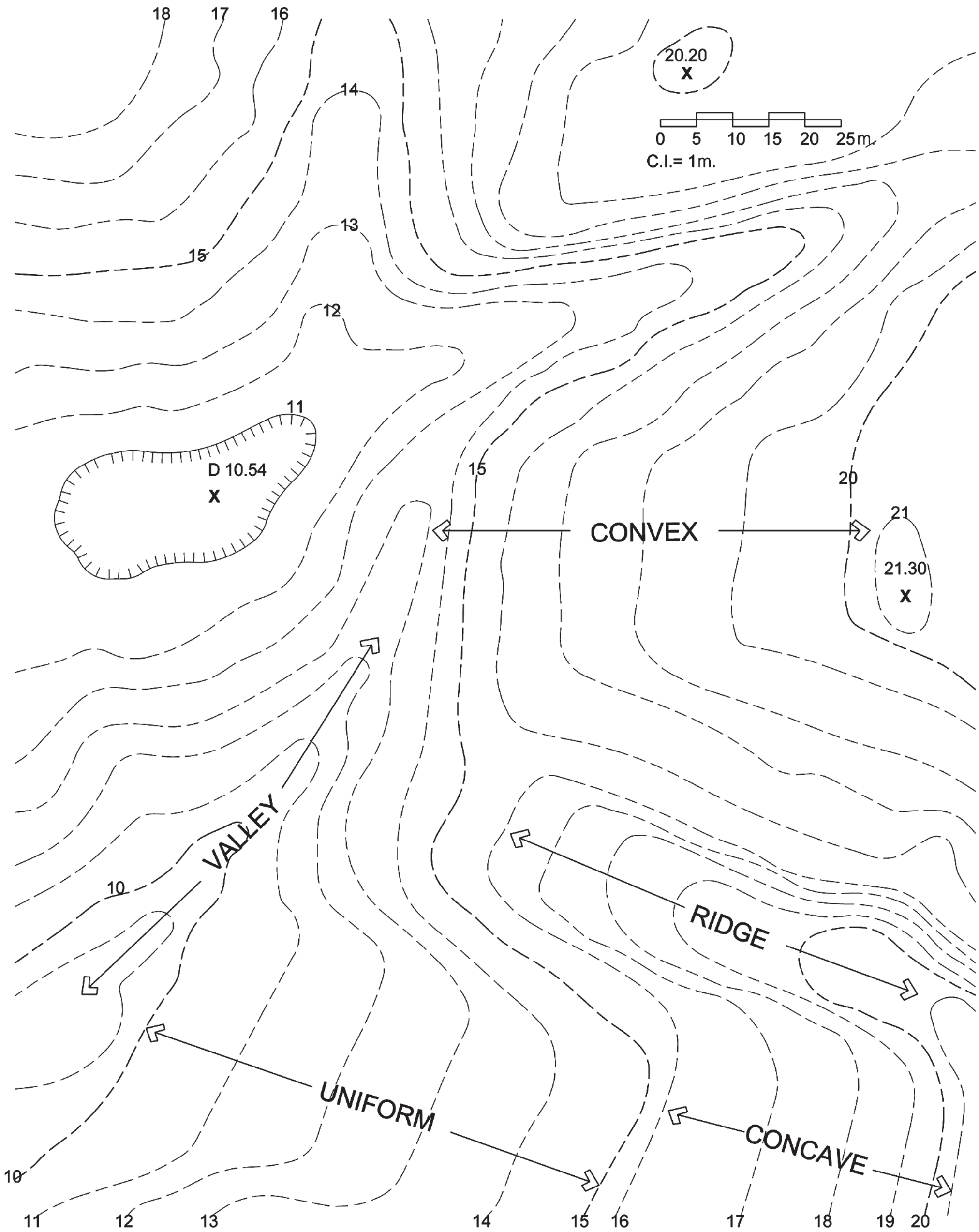


Figure 2.6 *A contour line can reveal different types of landform – mounds, valleys, ridges or gullies. The horizontal length shows the slope of the area and the base of the hill – uniform slope, concave or convex.*

2.3 Terms and definitions

The contour line is made to record the three dimensions of a landform with slopes so that it can be display on two dimensions. The two-dimension, plan is useful for construction purposes and is used internationally. As a result, terms of contour line adjustment are defined as follows:

The contour line is a line systematically joining points of the same level in the plan with a consistent contour interval.

Spot level, or spot elevation, is the height of a point expressed in meters, centimeters, millimeters from the height of reference such as the mean sea level. The architect, the structural engineer or the sanitary engineer of a project can use the same level reference such as FE (finished elevation) and RL (reduced levels). For engineering in general, a spot elevation is written with three decimals such as +48.356 meters. The spot elevation is used to specify a certain point in a construction plan that requires high definitions, level calculations, tell position and altitude of the peak or the lowest point of the site.

A contour map is a plan with many contour lines and each line joins points of the same elevation specifying a contour interval. A contour index can be included to be interpreted more easily such as a contour interval of 1 meter can have a contour index every 5 meters.

2.4 Abbreviations/symbols used in the contour plan

A contour plan contains elevations and symbols related to the contour grading that are used to communicate between landscape architects and/or engineers of different fields especially those that deal with drainage systems. The abbreviations and symbols that are generally used are:

	with contour elevation Existing contours represented by broken lines
	Proposed contours represented by solid lines. A change in the existing contour is represented by a dot.
59.2 x	Spot elevation
T.C. 25.1 x	Top of curb
B.C. 24.6 x	Bottom of curb
T.W. 25.0 x	Top of wall
B.W. 1.2 x	Bottom of wall
	A swale shows the direction of water flow
I.E. 10.25 x	Invert elevation
F.F. 10.00 x	Finished floor elevation F.E. (Finished elevation) can also be used.
H.P. 60.25 x	High point or H (Hill)
L.P. 50.21 x	Low point or D (Depression)
T.S. 0.25 x	Top of steps
B.S. 0.05 x	Bottom of steps
C.I. = 2.00	Contour interval
R.E. 10.25	Rim elevation
P L ▬ - - ▬ -	Property line (P.L.)
R.O.W. ▬ - - ▬ -	Right of way

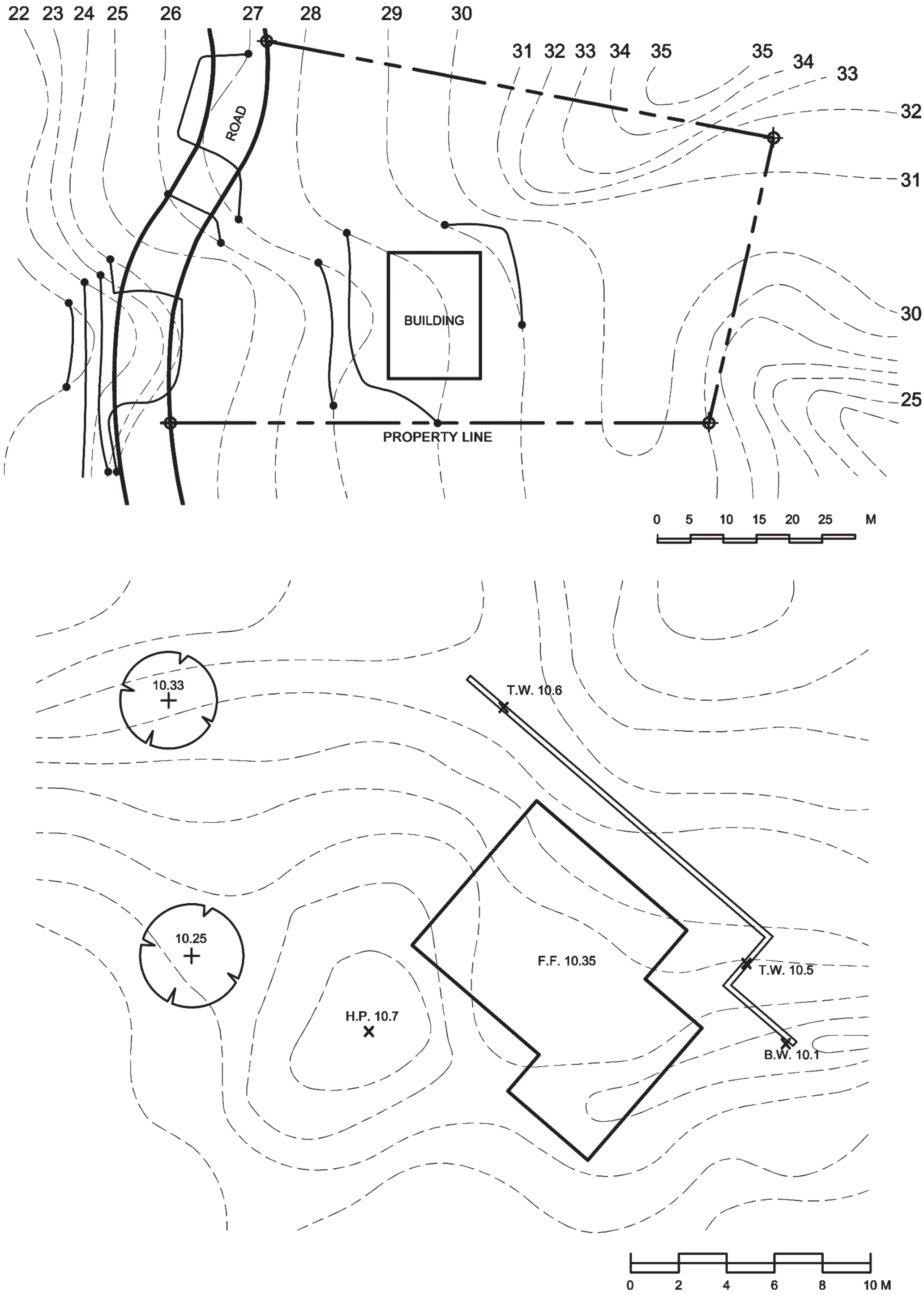


Figure 2.7 *The existing contour and the proposed contour*

C_L — · — · — · — Center line (C.L.)

D.I. Drain inlet. The elevation of R.E. and that of I.E. have to be specified.

S.D. Storm drain. The elevation of R.E. and that of I.E. have to be specified.

M.H. Manhole. The elevation of R.E. and that of I.E. have to be specified.

C.B. Catch basin. The elevation of R.E. and that of I.E. have to be specified.

A.D. Area drain. The elevation of R.E. and that of I.E. have to be specified.

2.5 Steps for creating contour lines

The relationship between elevation and landform can be divided into two types: spot elevations and contours. Sometimes both are used. Before the advent of a device that could create a contour plan instantly, the steps of creating the contour line were as follows:

Step 1: Determine the contour intervals which depend on the altitude, the slope, the definitions and the scale. For an area which altitude is not high, more intervals are needed. Sometimes each interval is expressed in every 0.25 meter (25 centimeters.). After that, an actual survey is carried out to determine the elevations and record them in the survey grid. The intervals are assigned as the architect sees fit.

Step 2: Creating a transit survey grid. If the area contains a waterway or a special characteristic, such an aspect has to be recorded. Based on the transit survey grid, locate the points that match the contour intervals.

Step 3: Draw a broken line joining different shades points of the same elevation. If the contour line is further divided by the index, of line or different color should be used to differentiate between the contour line and the index. The major lines should be more distinct than the minor lines.

Step 4: Assign numbers indicating elevation on the line.

Step 5: Identify the contour intervals with spot elevations on the peak and the valley in the plan.

Survey plan

Contour plan

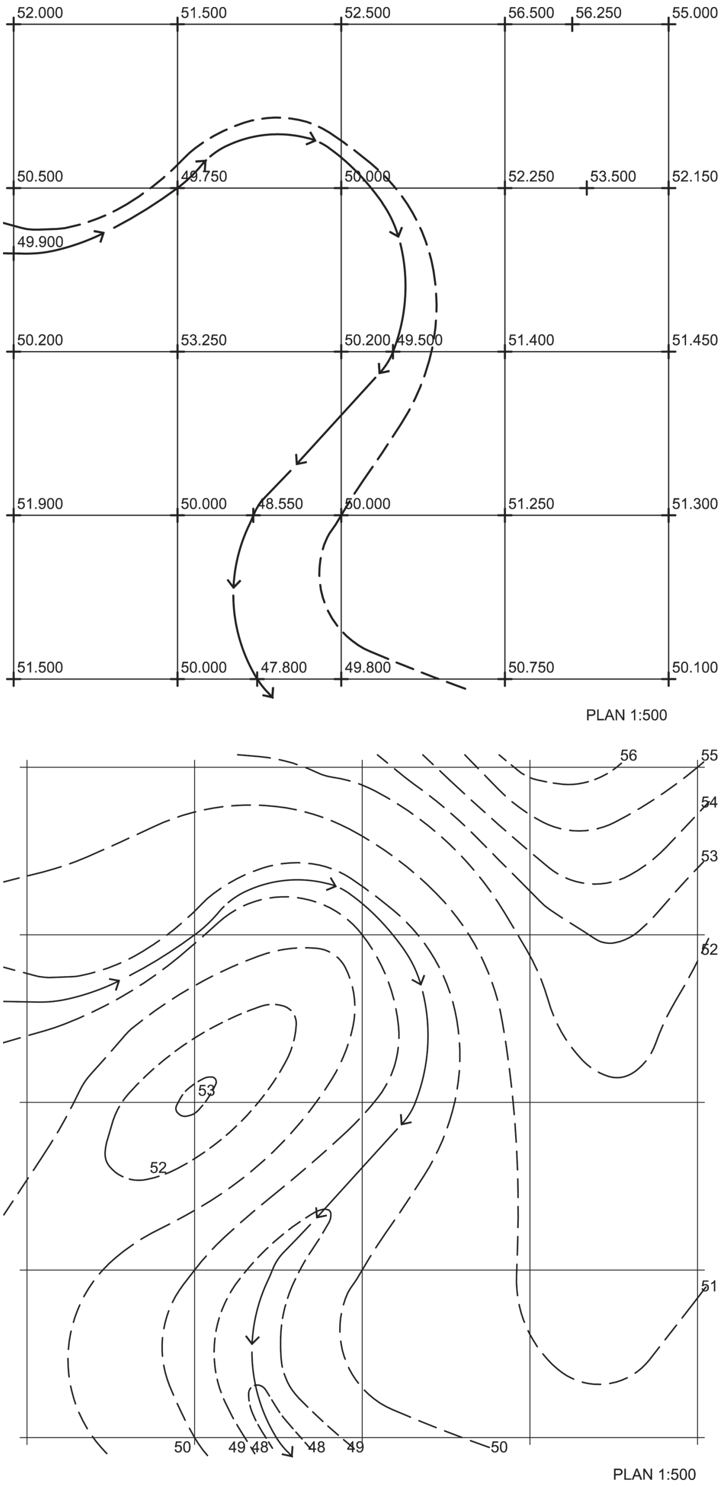


Figure 2.8 *Converting contour lines from a survey grid into a contour plan*

The contour lines cannot be crossed and the interval between each contour has to be the same. If the area is highly complicated, the index can be determined to facilitate the interpretation. If there is a waterway, the waterway and its flowing directions have to be present in the plan. The H.P., L.P., and other important points have to be identified.

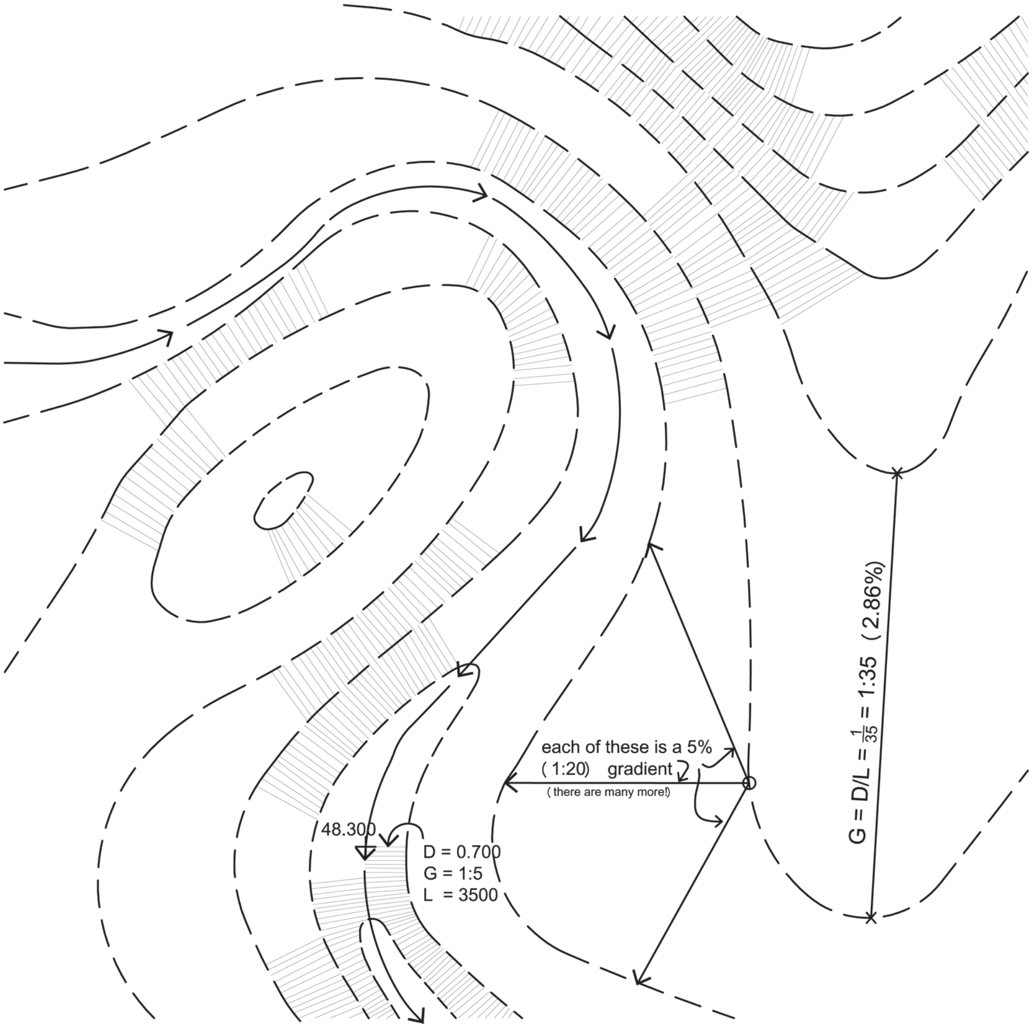
2.6 Drawing contour lines based on a survey grid

At present, elevations can be broken down to spots and can be changed into contour lines based on calculation and joining points could be carried out by a computer with minimal errors. With the old technique, the calculation could not be precise and the points had to be joined by hand. This required an experienced architect and the chances of making mistakes were high. If there was a problem, an actual survey was needed to collect more information, such as waterways, rocks and cliffs. The simple steps of drawing contour lines based on a survey grid are as follows:

Step 1 – Study the requirements of the project and how much contour interval should be in the plan. In this case (Figure 2.8) the contour interval is every 1.00 m.

Step 2 – Specify the position of the contour lines (from step 1). For example, between 50.50 and 52.00, there is 51.00 or between 49.75 and 53.25, there are 50.00, 51.00, 52.00 and 53.00.

Step 3 – Join the points of the same level.



Source: *712–Landscape Design. University of Canberra, Australia*

Figure 2.9 *Slope analysis technique and determination of spot elevations based on the contour plan*

Figure 2.10 *Children's playground Takino Federal Park, Hokkaido (above) and bronze sculptures (below). Contour grading makes the park blend in with the natural features of the site.*

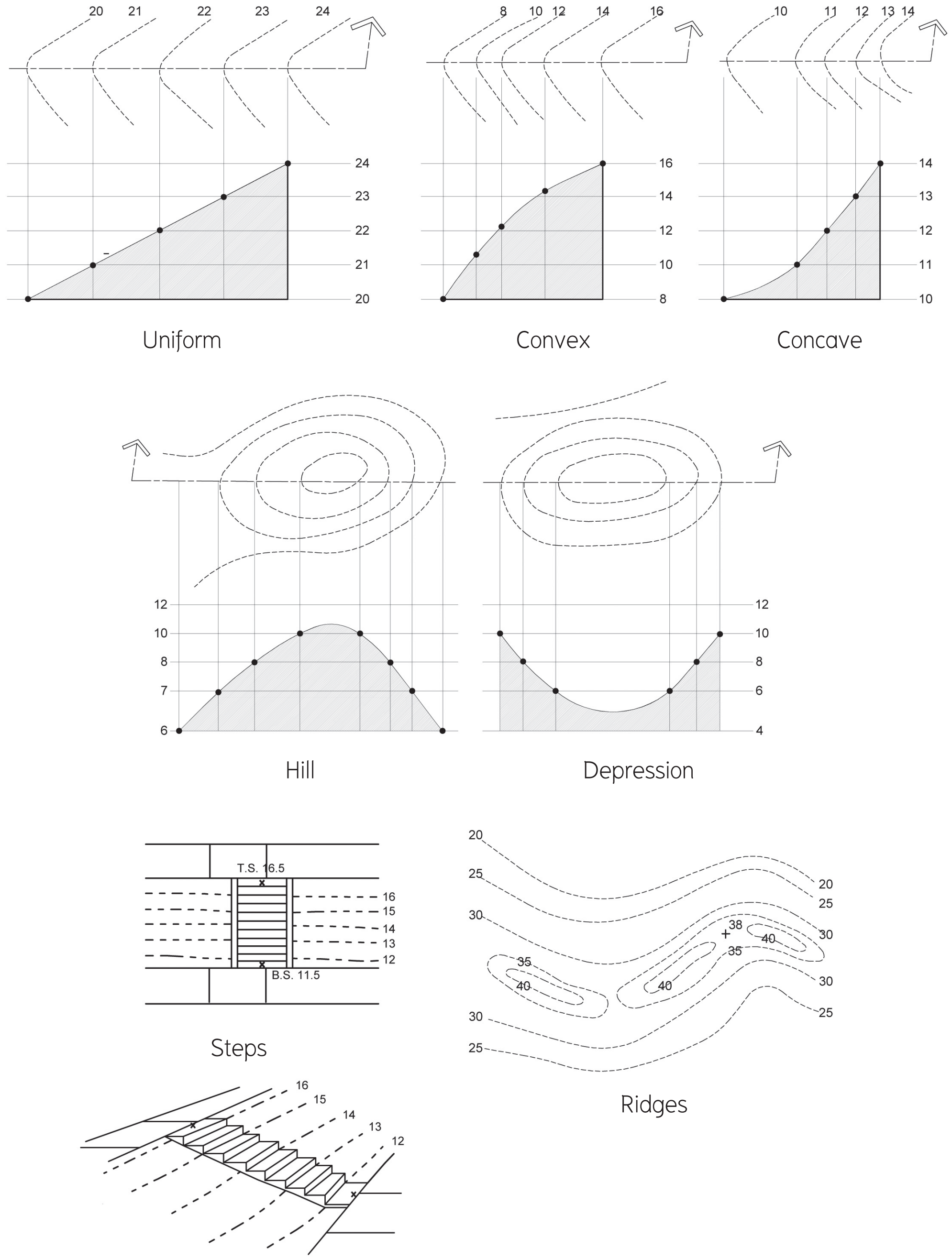


Figure 2.11 Contour signatures

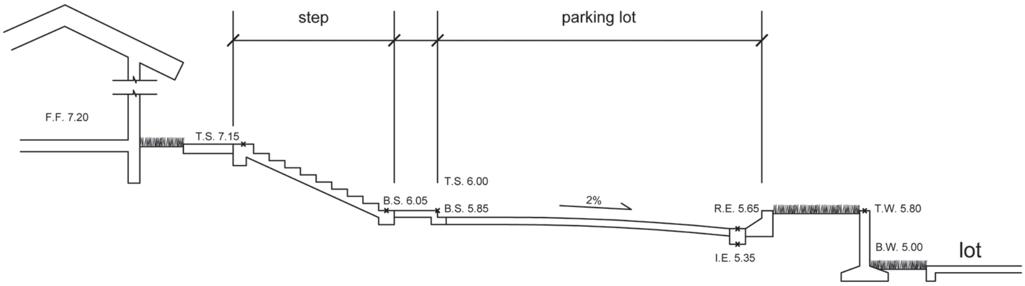


Figure 2.12 *The profile shows the numbers of spot elevations*

2.7 Points that should be specified

In the contour plan, there are points that cannot be shown by a contour line; therefore, spot elevations are assigned using the symbol X. Numbers are assigned to each spot elevation and they are written over the X. The following spot elevations should be specified.

1. The ground floor that is represented by F.F. (Finished floor, Finished grade).
2. All corners of the building, the entrance or the landing that are represented by the finished grade.
3. All corners of the parking area, porch or other hard surfaces that are represented by the finished grade.
4. All corners of the top landing and the base of the last step. The top step is T.S. and the bottom step is B.S.
5. Top of Curb and Top of Wall are T.C. and T.W., while Bottom of Curb and Bottom of Wall are B.C. and B.W., respectively.
6. The highest point of a rock and the base of a big tree.
7. The lid and invert elevation of a catch basin are represented by R.E. and I.E., respectively.

2.8 Properties of contour plans

The contour plan shows the consistency of contour intervals, the index if the area is highly complicated so that the plan can be easily interpreted, the waterway and its directions, H.P., L.P. and other important spot elevations. Generally, the contour lines are not crossed except if there is a protruding ledge or a natural stone bridge in the area. The slope is interpreted from the length between the contour lines. The closer the contour lines, the steeper the slope. The uniform length between the contour lines indicates the uniform steepness of the slope. For the concex slope the lower contour lines are closer than the higher one and for the concove slope is the opposite. As for the concave slope, the contour lines range from the low level to the high level. Contour lines showing the low level are further away from each other than those showing a high level (Figure 2.11). The properties of the contour plan are:

1. each point on the same contour line has the same spot elevation.
2. one end of a contour line always meets the other end. The meeting point can be in the plan or outside the plan.
3. The contour lines that meet and show an inner ring refers to a Hill (H) or a Depression (D). Within the loop of the contour line, coordinates have to be specified with D (Depression), L.P. (Low Point) in the case of an abyss. In the case of a Hill or Peak, H (Hill) or H.P. (High Point) is used.
4. the contour lines are not crossed, but they are in the case of a protruding ledge or natural stone bridge.
5. the consistent length between the contour lines means uniform slope.
6. as for the convex slope, the contour line climbs from a low to high level and the high-level contour lines are further away from each other than the low-level contour lines.

7. as for the concave slope, the contour line climbs from low level to high level and the low-level contour lines are further away from each other than the high-level contour lines.

8. the valley is interpreted from the contour line climbing up towards the higher-level contour lines.

9. the closer the contour lines, the steeper the slope.

10. the further away the contour lines, the less inclined the slope.

11. the contour lines are unified. The same contour lines that are close to each other indicates a high or low level. If the numbers are on the same side, this indicates a high level but if they are on the opposite side, this indicates a low level.

2.9 Benefits of contour plans

The contour plan enables the architect to

1. know the nature of surface runoff.
2. identify problematic spots by looking at the contour lines, conduct slope analysis and calculate drainage pattern.
3. use it as the base for making a grading plan.
4. plan earth work.

2.10 Contour signature

The contour signature assists the landscape architect to understand landform. The contour lines show slope, gully, water channel, drainage ditch/swale, ridge, flood plain, dale/ravine, knoll/knob butte, camel back ridge, bay, meadow, dry swale, steps, alluvial fan, toe, saddle, bridge/block culvert, retaining wall, and turtle-back swale.

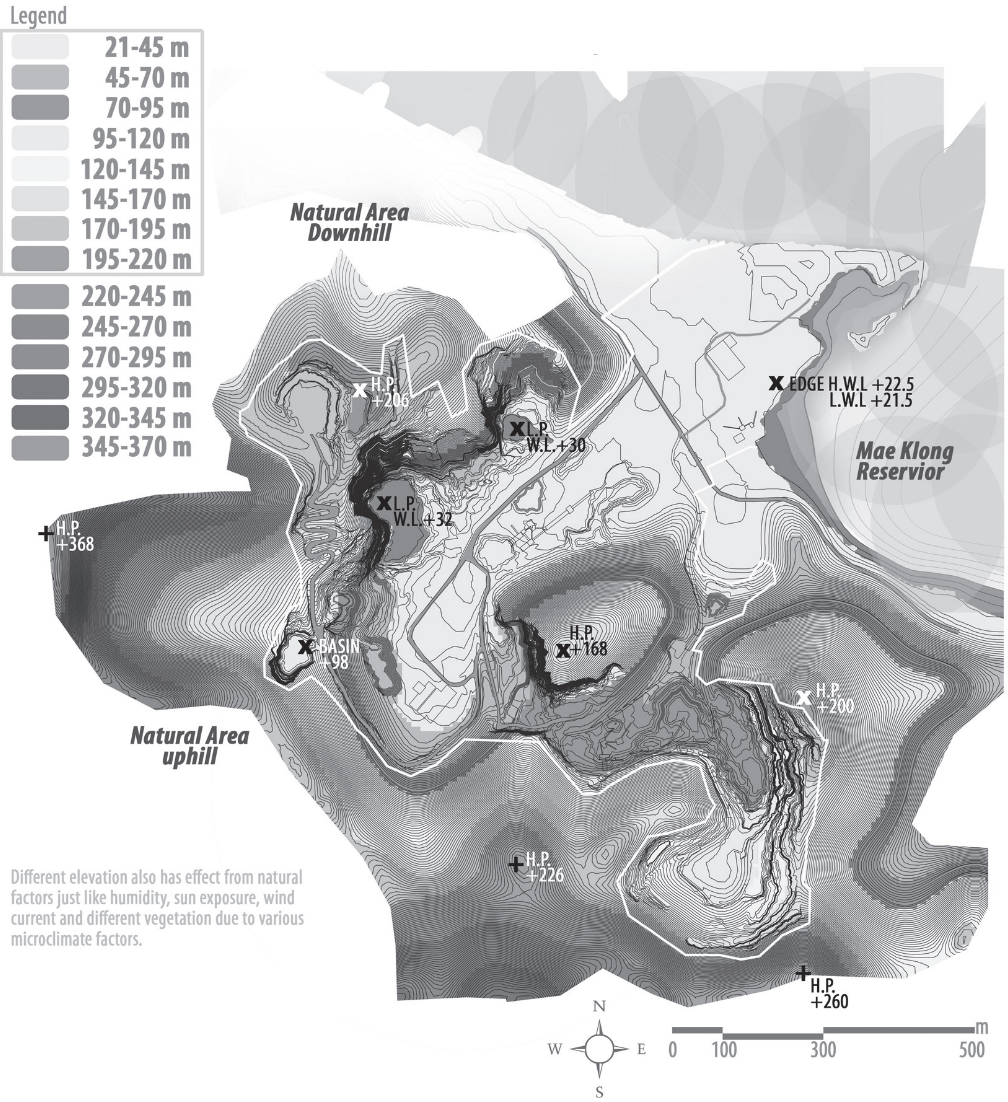
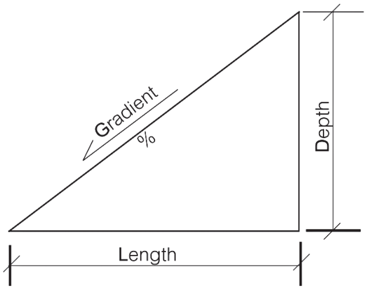


Figure 2.13 *Elevation analysis presented in an undergraduate thesis "A Public Park Project: Reclaiming and Developing a Limestone Mine in Kanchanaburi, Thailand" by Akarapol Chongwattanaroj, Department of Landscape Architecture, Faculty of Architecture, Chulalongkorn University*

At present, there is a computer program that can create contour lines and simulate landforms in three dimensions based on the survey information so it is easier to analyze the area and carry out the grading plan. However, a contour signature is still essential for the landscape architect because he can design a suitable grading plan and drainage system in line with the landform, which is considered good practice.

2.11 Landform analysis

As the contour plan reveals the geographical conditions of that area, the interpretation of slope, visual quality, and space enclosure can be done two ways: project intersection and hollow core model. As for the first, the area is seen in terms of spots in which the lines are crossed while in the second, the area is seen as a whole in which the slope is determined by horizontal length.



Formula to calculate is $G = \frac{D}{L} \times 100$

D = Vertical depth

L = Horizontal length

G = Gradient which is expressed in %

The same formula can be applied for slope analysis and will be explained later.

2.12 Slope analysis

To design the landscape of a large area, the contour plan has to be interpreted so that the landform can be analyzed. General analysis covers slope analysis technique and elevation analysis technique. Elevation analysis can be done by coloring the area between the contour lines. Different colors are used, ranging from green representing the basin near the mean sea level to red or brown representing the apex of a hill. Blue represents a water source that is lower than mean sea level. Slope analysis requires calculation and estimation to find a slope area that is divided into categories according to the requirements of the project. For example, it can be divided into four categories as follows:

a plain (slope is less than 5%)	– suitable for all construction
a slight slope (slope is 5-10%)	– suitable for constructing a building but unsuitable for a stadium
an average slope (slope is 10-15%)	– can only be used to construct certain types of building
a steep slope (slope is more than 25%)	– special construction techniques are required to manage problems

When the slope analysis is done, horizontal length has to be obtained based on D = GL D = Vertical depth and G = Category and number of contour intervals. If the contour intervals are 5 meters, so

G = D/L and L is what need to be identified.

L = D/G

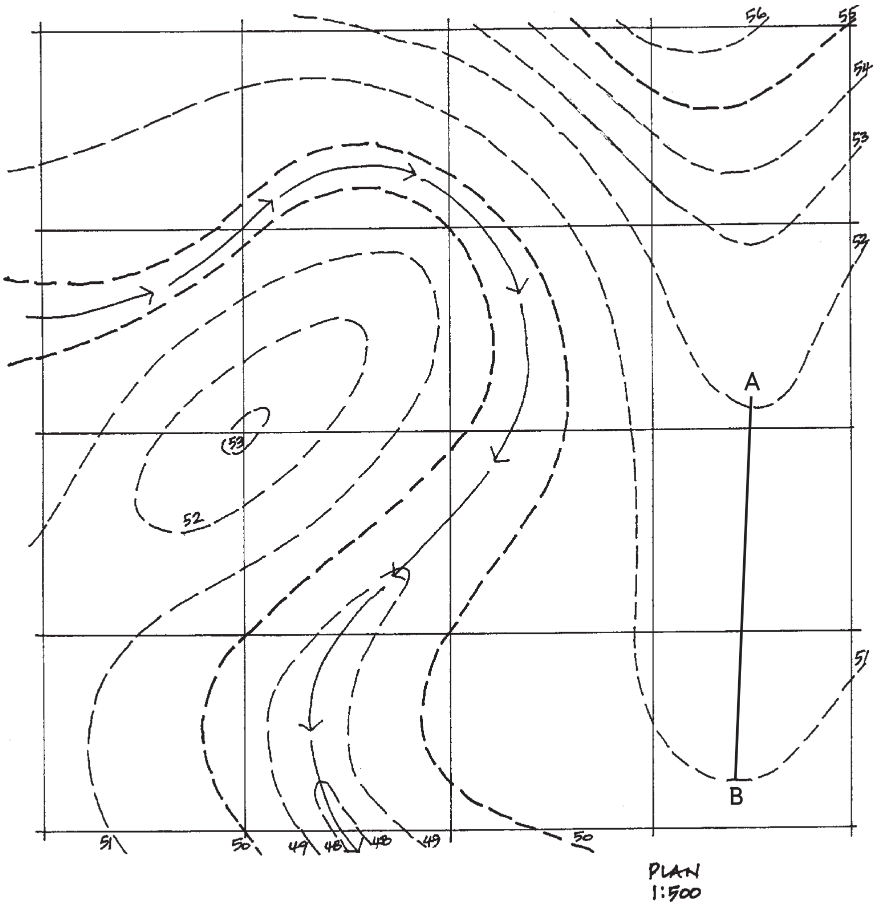
G	=	< 5%	L	=	5/0.05	>	100
G	=	5-10%	L	=	5/0.1	=	50
G	=	10-25%	L	=	5/0.25	=	20
G	=	> 25%	L			<	20

Then L is used to determine the horizontal length in the plan based on the right-angle line between the contour lines.

As mentioned earlier, the closer the contour lines, the steeper the slope while the further away the contour lines, the gentler the slope. If the horizontal length between two lines (the contour interval is 5.00 meters) is more than 100 meters, this indicates the gradient is less than 5%. If the length is 50-100 meters, this indicates the gradient is 5-10%; the length is 20-50 meters, this indicates the gradient slope is 10-25%; and the length is less than 20 meters, the gradient is more than 25%.

<u>Drawing a slope analysis</u>

<u>Question</u> According to the survey contour plan and the plotting of contour plan determine the slope from point A to point B. Draw a line between 2 contour lines with gradient of 5%. They can be any line but their slope is 5%. Color the areas whose slope is greater than 20%.



1. Determine gradient of the slope between point A and point B

   The distance from point A to point B = 35 m. = L

   D = 51 – 52 = 1

   D = GL

   1 = G x 35

   G = 1/35 = 2.86%

2. Draw a line between any two contour lines with gradient of 5%

   G = 5% = 0.05

   D = 1

   D = GL

   1 = 0.05 x L

   L = 1/0.05 = 20.00 m.

Then draw a line so in long between two contour lines where difference is 1.00 meter to be 20.00 meters long.

3. Color the areas with gradient of more than 20%

   G = 20% = 0.20

   D = 1

   D = GL

   1 = 0.2 x L

   L = 1/0.2 = 5.00 m.

Then draw a line around the boundary between two contour lines whose horizontal length is less than 5.00 meters.

The slope analysis of another area should follow the third step to determine L based on G.

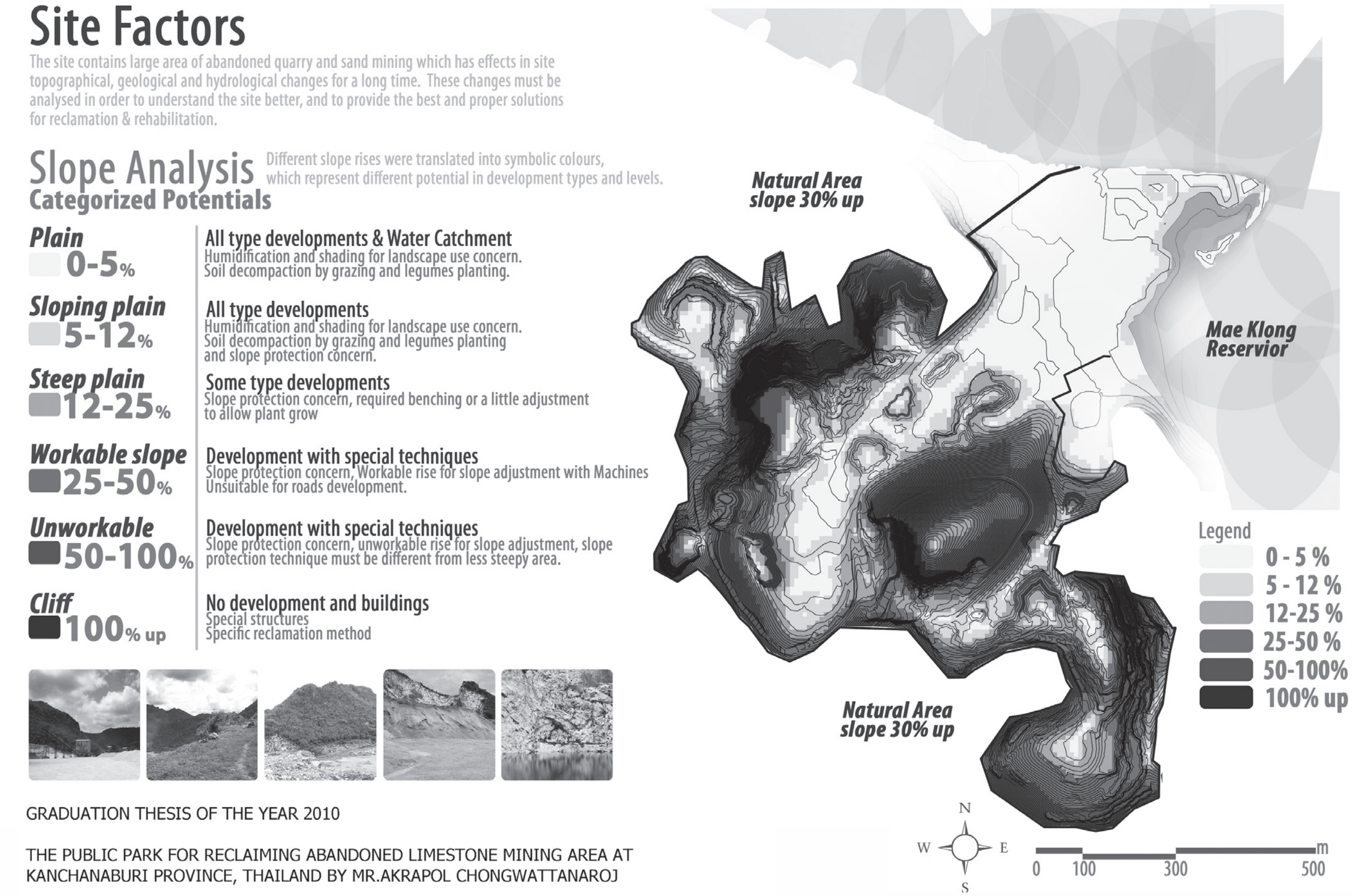
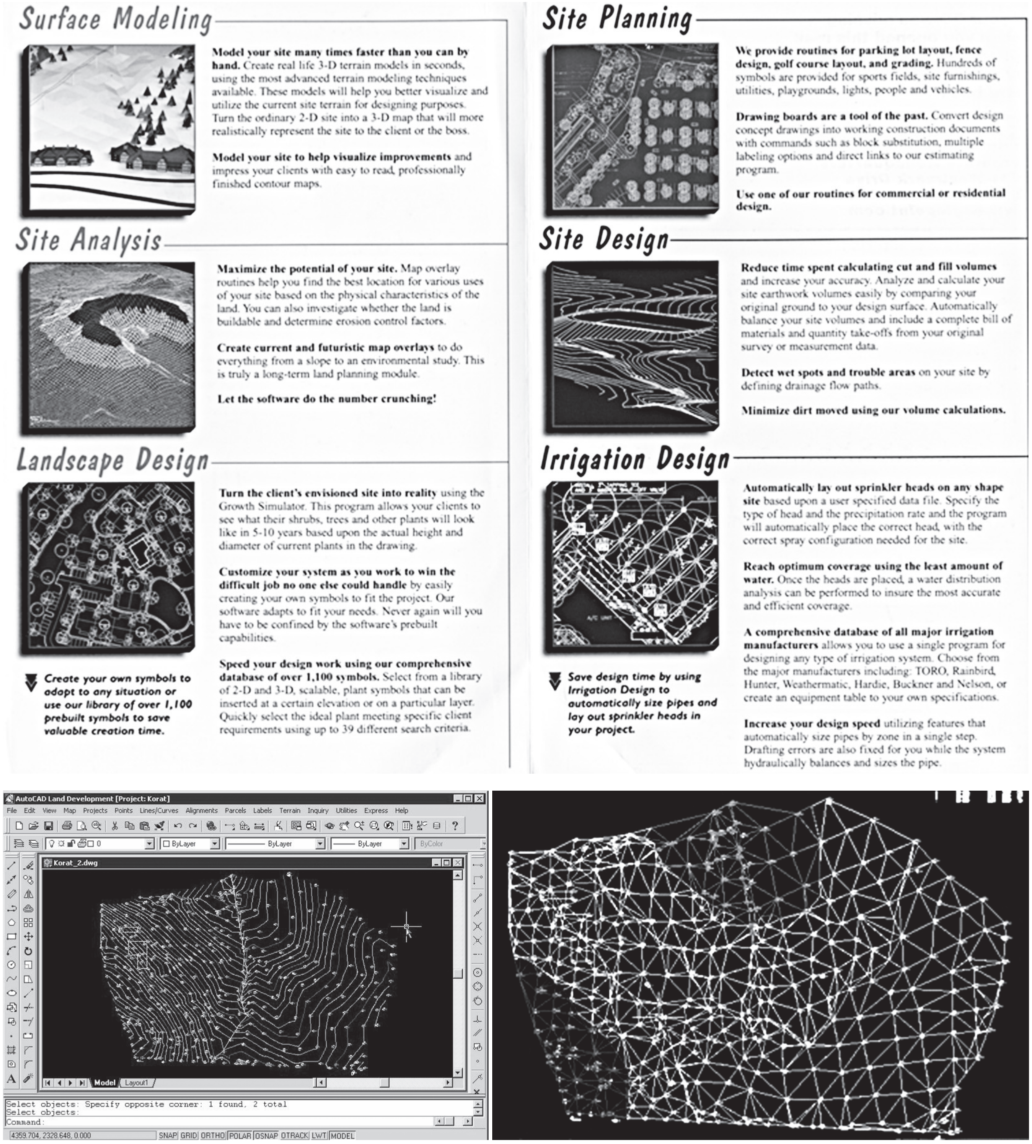


Figure 2.14 *Slope analysis presented in an undergraduate thesis "A Public Park Project: Reclaiming and Developing a Limestone Mine in Kanchanaburi, Thailand" by Akarapol Chongwattanaroj, Department of Landscape Architecture, Faculty of Architecture, Chulalongkorn University*



Surface Modeling

Model your site many times faster than you can by hand. Create real life 3-D terrain models in seconds, using the most advanced terrain modeling techniques available. These models will help you better visualize and utilize the current site terrain for designing purposes. Turn the ordinary 2-D site into a 3-D map that will more realistically represent the site to the client or the boss.

Model your site to help visualize improvements and impress your clients with easy to read, professionally finished contour maps.

Site Analysis

Maximize the potential of your site. Map overlay routines help you find the best location for various uses of your site based on the physical characteristics of the land. You can also investigate whether the land is buildable and determine erosion control factors.

Create current and futuristic map overlays to do everything from a slope to an environmental study. This is truly a long-term land planning module.

Let the software do the number crunching!

Landscape Design

Turn the client's envisioned site into reality using the Growth Simulator. This program allows your clients to see what their shrubs, trees and other plants will look like in 5-10 years based upon the actual height and diameter of current plants in the drawing.

Customize your system as you work to win the difficult job no one else could handle by easily creating your own symbols to fit the project. Our software adapts to fit your needs. Never again will you have to be confined by the software's prebuilt capabilities.

Speed your design work using our comprehensive database of over 1,100 symbols. Select from a library of 2-D and 3-D, scalable, plant symbols that can be inserted at a certain elevation or on a particular layer. Quickly select the ideal plant meeting specific client requirements using up to 39 different search criteria.

Create your own symbols to adopt to any situation or use our library of over 1,100 prebuilt symbols to save valuable creation time.

Site Planning

We provide routines for parking lot layout, fence design, golf course layout, and grading. Hundreds of symbols are provided for sports fields, site furnishings, utilities, playgrounds, lights, people and vehicles.

Drawing boards are a tool of the past. Convert design concept drawings into working construction documents with commands such as block substitution, multiple labeling options and direct links to our estimating program.

Use one of our routines for commercial or residential design.

Site Design

Reduce time spent calculating cut and fill volumes and increase your accuracy. Analyze and calculate your site earthwork volumes easily by comparing your original ground to your design surface. Automatically balance your site volumes and include a complete bill of materials and quantity take-offs from your original survey or measurement data.

Detect wet spots and trouble areas on your site by defining drainage flow paths.

Minimize dirt moved using our volume calculations.

Irrigation Design

Automatically lay out sprinkler heads on any shape site based upon a user specified data file. Specify the type of head and the precipitation rate and the program will automatically place the correct head, with the correct spray configuration needed for the site.

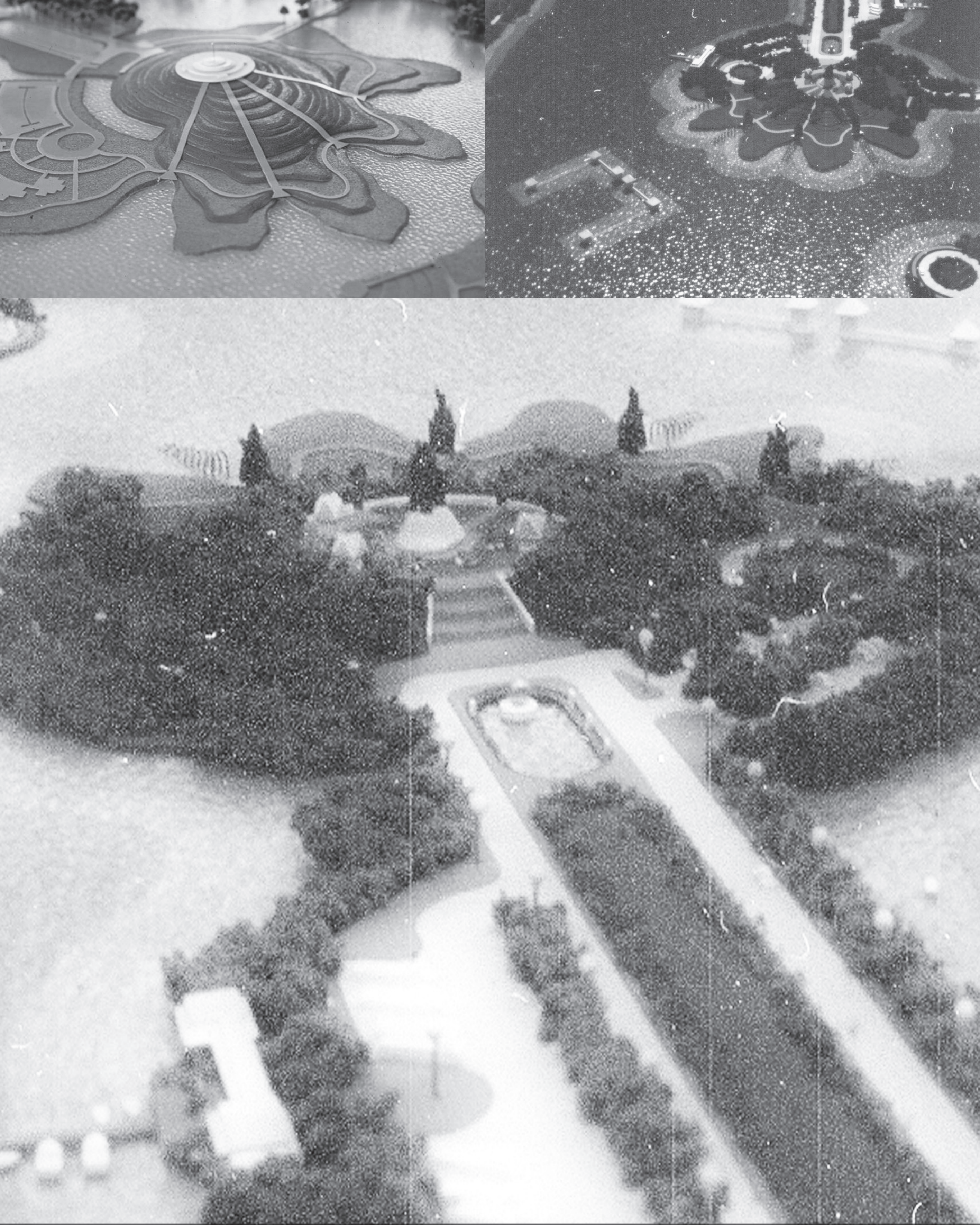
Reach optimum coverage using the least amount of water. Once the heads are placed, a water distribution analysis can be performed to insure the most accurate and efficient coverage.

A comprehensive database of all major irrigation manufacturers allows you to use a single program for designing any type of irrigation system. Choose from the major manufacturers including: TORO, Rainbird, Hunter, Weathermatic, Hardie, Buckner and Nelson, or create an equipment table to your own specifications.

Increase your design speed utilizing features that automatically size pipes by zone in a single step. Drafting errors are also fixed for you while the system hydraulically balances and sizes the pipe.

Save design time by using Irrigation Design to automatically size pipes and lay out sprinkler heads in your project.

Figure 2.15 *Land Development Desktop, by Autodesk, a computer program that can make a contour plan, analyze landform, analyze water flow, grade the contours, make sections/profiles and calculate earth work*



Queen Suriyothai Memorial Park in Makham Yong Field, Ayutthaya. They are examples of grading conceptual design and to retain water.

Chapter 3

Grading

3.1 Preface

Example from past and present landscape architecture projects show that grading is a key element in landscape architecture especially in projects that involve water retention, detention areas and drainage systems, projects that run a risk of flooding and projects that have to be built on slopes. The Queen Sri Suriyothai Memorial Park at Thung Makham Yong field in Ayutthaya is a perfect example of grading to make that area a water detention while making a mound for the monument. It also signifies different meanings from different perspectives but with visitors sharing the same feelings (Ariya Aruninta, 2006).

3.2 Planning by taking geographical conditions into consideration

Another important element in design is taking geographical conditions into consideration and disturbing them the least. A landscape architect has to look for a suitable approach to reclaim and develop that area while preserving the natural features of that area. The following are examples of projects that pay respect to nature by disturbing the site the least.

Figure 3.1, 3.2 *Grading is carried out for vehicle purposes at Rajaprapa Dam (left) and for pleasant scenery in Tokachi Millennium Forest, Hokkaido (right)*

3.2.1 Millennium forest – A micro climate created by geographical conditions. The area behind the knoll to the north is not exposed to the sun so the temperature is lower than other parts of the site. Takano Landscape takes advantage of this and makes the knoll an interesting spot – letting the vegetation grow naturally; as a result, the vegetation in front and that behind the knoll grows differenlty. The interesting aspects lie in their texture, shadow, and movement in the wind.

Figure 3.3 *Parterres with different levels are used in the garden in Versailles Palace, creating a unique perspective. One can see the whole of the lower land from the top and enjoys the enclosed space of the lower terrace.*

3.2.2 Road works in the Rajjaprabha Dam – In places that are hilly, roads will be built around the hill so as to make the slope gentler but this makes the roads longer and winding. Lombard Crooked Street in San Francisco is the most famous road of this kind since the land is hilly, and the road therefore has to be built along the contour lines to facilitate the traffic. The grid road is usually built on flat ground.

3.2.3 Versailles Palace – although the drainage system is a problem that triggers grading so that the area can serve to the fullest of its potential functions in addition to being more beautiful. As for this palace, the gardens along the main axis are of different levels. From the palace, one can see the gardens rolling out to the end of the horizon. This kind of grading is also applied to the designing of a public park, a memorial park and an outdoor museum. Functions can be assigned to fit different landforms but perspectives, space and atmosphere of the land also play an important role. The landscape architect has to take landforms into consideration and try to disturb the site the least. He has to highlight the natural features of the site as well.

In the past, gardens were designed according to the different geographical conditions. For example, the Italian garden is terrace-like to fit the flow and the pressure of water (fountains) that is a key element of this garden while in the French garden, uses plain area or a slight different in level to create a panoramic view like the garden in Versailles Palace. Each room of the garden offers its own view enclosed by partition and to give peace and serenity to the garden.

3.2.4 Queen Suriyothai Memorial Park – the grading creates different perceptions. From the two main entrances, one can see the exquisite memorial on the hill and before walking up the steps, one can see her subjects sitting with sadness. However, one cannot see what is behind the memorial mound so one feels curious and has to go to the top of the terrace to satisfy one’s curiosity. When standing on the top of the memorial to the northwest, one can see the enemy troops down below near the reservoir and the enemy camps in the reservoir. This implies that the enemy troops that surrounded Ayuttaya had to retreat during the rainy season because this area was flooded.

Schematic design helps a landscape architect decide whether that area has to be filled since reclaiming an area may lead to other problems, and it is irreversible.

3.3 Designing and grading

Grading aims to improve a landform for certain functional purposes or for aesthetic purposes and is one of the most important part of the Landscape

Arichitectural Design. Landscape architects have to consider the law of nature such as the repose angle, the surface drainage and the effects on neighboring areas when they plan to grade the site. As for an uneven area, architects have to study the project requirements and design the landscape to fit the requirements and blend in with the natural features by disturbing the site the least. By doing this, the architects can save time and budget for earth work. Grading an uneven area requires slope analysis, surface drainage analysis, visual analysis and micro climate analysis based on the profile, the section or the model of that site.

Then the architects design the functional areas, the drainage system and the grading plan as well as the schematic design.

3.4 Technical terms

Technical terms for grading are different from those of civil engineering and of landscape architecture, in particular, the ratio (L : D or D : L). As for civil engineering, the formula G = D/L (D : L) is used while G = D/L but (L : D) is used in landscape architecture. The following are common grading terms.

Maximum slope is the ratio of the steepest slope that is suitable depending on the material of the slope expressed in L : D.

Solid rock	1/4 : 1
Loose rock	1/2 : 1
Gravels	1 1/2 : 1
Hard clay	1 1/2 : 1
Soft clay	2 : 1
Grassy hill that needs cutting (by lawn mover)	3 : 1

A gradient is the percentage of the rise and the run of slope per 100 meters. For example, a 4% gradient refers to a slope that is raised by 4 meters at the horizontal level of 100 meters.

A crown is the level of the middle of the road or walkway raised for drainage. The length is measured from the highest point to the lowest point and expressed as a round number such as 0.10 meter.

A cross slope or pitch is the slope of a paved area for drainage either expressed as a percentage such as 1% or a decimal such as 0.05 meter.

A wash is a sloping upper surface of stepping structure to carry water away. The inclination (L : D) is expressed as 1 meter horizontally per vertical unit (in centimeter) or as a percentage.

A batter is a uniformly steep slope inclining from the vertical. The inclination (L : D) is expressed as 1 centimeter horizontally per vertical unit (in meter) or as a percentage.

A slope is a ratio of L : D such as 3 : 1.

3.5 Purposes of grading

In the past, grading aimed to:

1. To make the area suitable for its functions, such as buildings, transportation, sports grounds. Areas with different function need different type of ground. For example, a sport ground requires a horizontal area while a road can be both flat and uneven. The maximum slope will depend on the different types of usage. The slope for a ramp for handicap people should not be more than 8%. A structure on a steep slope is usually a small or step-like structure.

2. improve drainage so the surface runoff will not damage the site. Grading helps slow the flow of water so the water will not erode the surface soil. In addition to slope caused by grading, covered vegetation, quantity of water and its flow can cause soil erosion at different rates.

3. improve landform that can adversely affect human activities. A slope can cause soil erosion and landslide as well as obstruct land use and transportation. Proper grading can solve such problems.

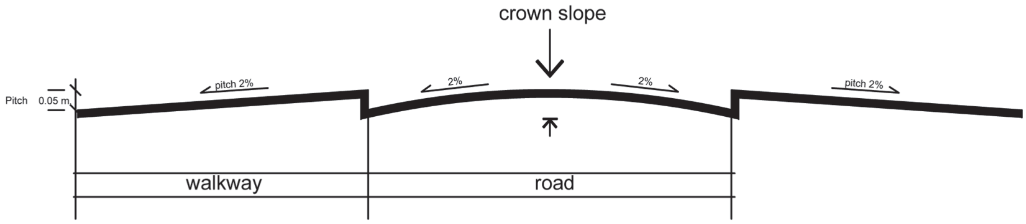


Figure 3.4 The cross section showing the crown slope of a road and the pitch tilt or the cross slope of a walkway

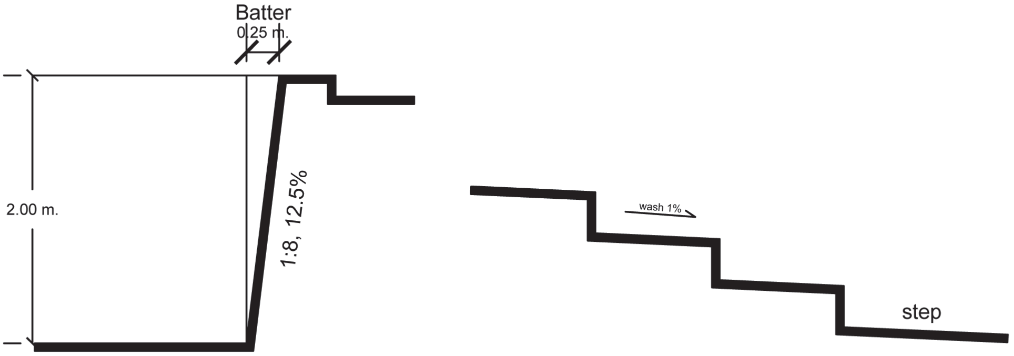


Figure 3.5 The cross section showing the batter distance of a retaining wall soil (left) and the wash slope of steps (right)

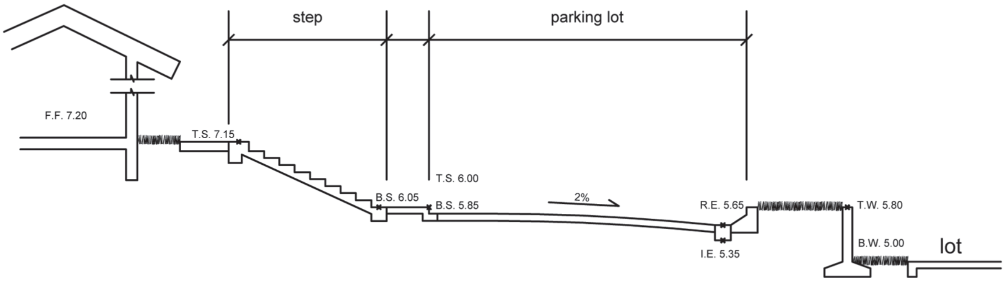


Figure 3.6 The cross section showing how to specify the slope as % or spot elevation of a walk, walkway edges, and drainage direction.

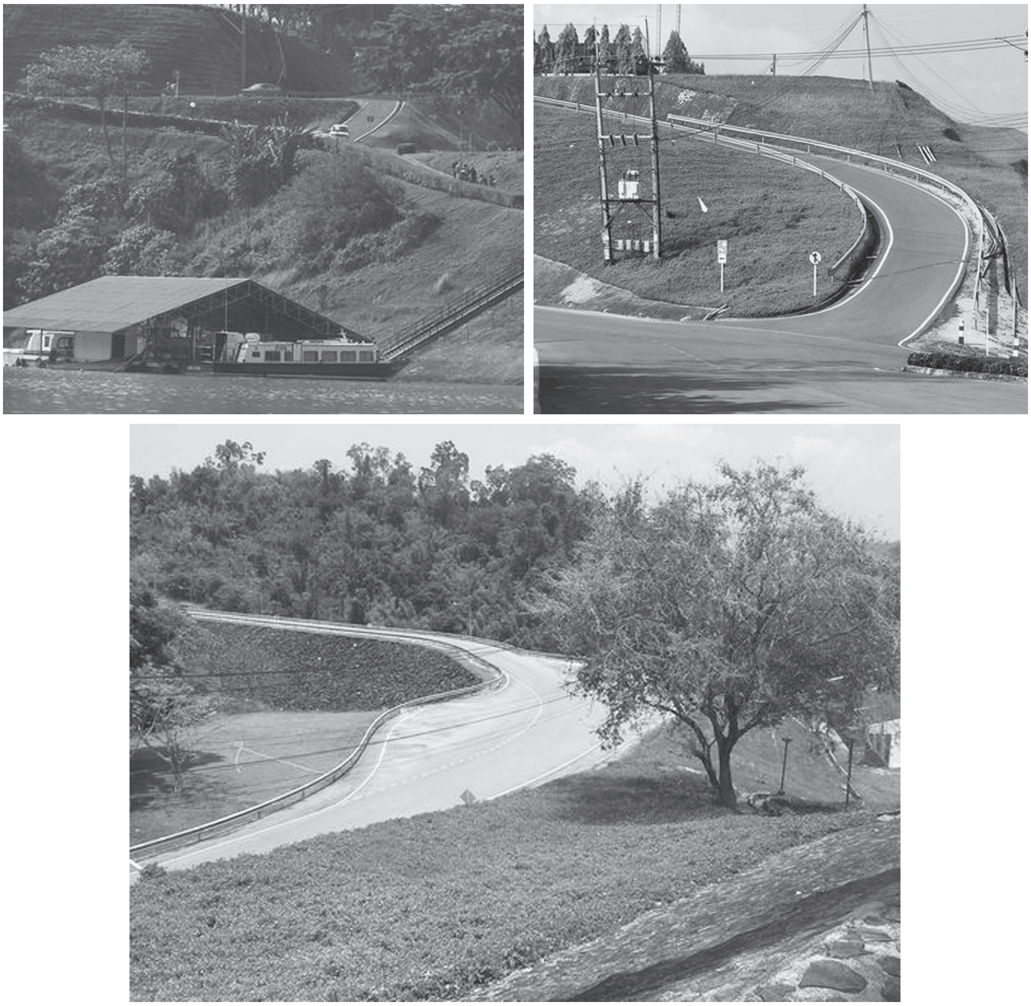


Figure 3.7 *An example of grading for an area to make it suitable for traveling in Rajaprapa Dam*

4. protection against, wind or unwanted sight. For example, grading can screen an unpleasant sight such as a view of a parking lot seen from a club house.

5. increase the depth of the earth to grow a big tree. For example, if the level of the underground water is high, ridging is a suitable approach.

6. emphasize on geological condition and travelling routes grading by molding the ground into mound and trough canbe use to designate the router and also control the view of the land. This kind of grading is used together with the Road Alignment design on Scenic Routes.

7. beautify the site by creating a terrace landform to blend in with the foliage and flowering plants such as the landscape of a resort.

In short, grading aims to carry surface drainage, create a berm to protect the site from sound or wind, increase the volume of soil for growing trees, create a plain for a sports ground or a parking lot, limit road alignment, beautify the site, screen an unpleasant sight and create a suitable spot for a certain structure.

However, the concept about drainage system has been changed from draining the surface runoff to the public drainage system, to changing an area into a retention or detention area. At present, grading focuses on water management by integrating best management practice as carried out in the United States or employing integrated urban water management and water-sensitive urban design as carried out in Australia. Such practices will be discussed in details in Chapter 4: Drainage and in Chapter 14: Green Design Concepts.

3.6 Points to be considered in grading

Before grading, information about the site has to be collected for analysis to obtain a proper grading approach. As a result, a landscape architect has to realize that:

1. the graded site should blend in with the surroundings. For example, if the site is hilly, he should keep the site as natural as possible and design a structure to fit the setting.
2. A thorough study of the site limitations such as the laws related to the site grading, the micro climate, public utilities both on the surface level and the underground level, surface drainage and vegetation. If there is a lot of vegetation, they should be preserved and filling the site to prevent floods can damage the vegetation.
3. the grading should serve the purposes of the land use, in that, a landscape architect has to decide which slope fits which activity.

4. the cut and the fill has to be balanced in order to save costs.

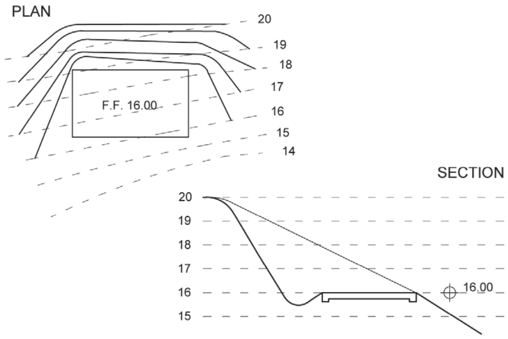
5. the grading has to facilitate and not to obstruct the construction.

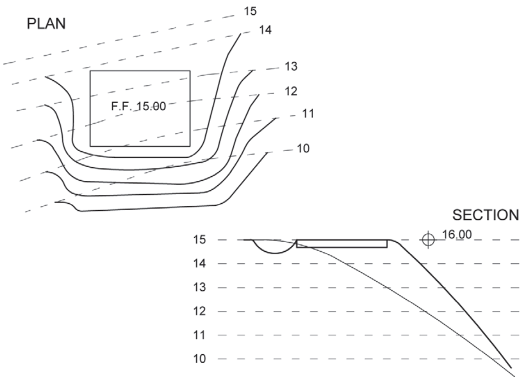
Two major questions concerning grading are how to grade it and when it should not be done. The first deals with "playing" with the landform and the second deals with limitations such as landform, machinery, construction cost, water management, ecological management and aesthetics.

3.7 Methods of grading

Grading is changing or fixing landform that can be done in four ways.

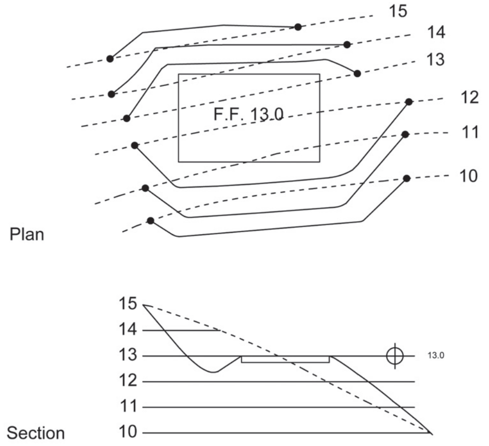
1. Cutting is a change in landform by taking a certain amount of earth out of the site. The foundation of a structure is on the horizontal level and it provides stability and sustainability since it can bear heavy loads and there is a small chance of soil erosion. There are, however, some disadvantages; for example, the cost of earth works is high because the project owner has to pay for the trucks to carry the earth out of the site and for the rent of land where the earth will be dumped. It is not advisable to dump the earth in the catch basin since it can be a water retention area.





2. Filling is carried out when a low land is going to be used but the earth from another

area has to be carried to the site and this will also cost a lot of money. Filling leads to soil erosion because the earth is loose. Plus, the newly-filled area is not stable enough to build a structure so compaction is needed. Compaction also poses a problem when trees are planted.



3. Cut and fill is the most popular approach. The cut and fill will balance the earth taken away and filled; as a result, this will reduce the expenditure on cutting and filling. The earth taken away from an area can be used in the landscape, in another area of the same site, parking lot or other facilities such as sports grounds. However, engineering techniques are required to prevent landslide around the cut and filled areas. The top soil has to be preserved for tree growing and for soil erosion prevention.

4. Retaining wall or step is another approach to grade landform but both cost more than the other three approaches. However, at present, there are ready-made material that can replace the wall or the step such as a gabion box.

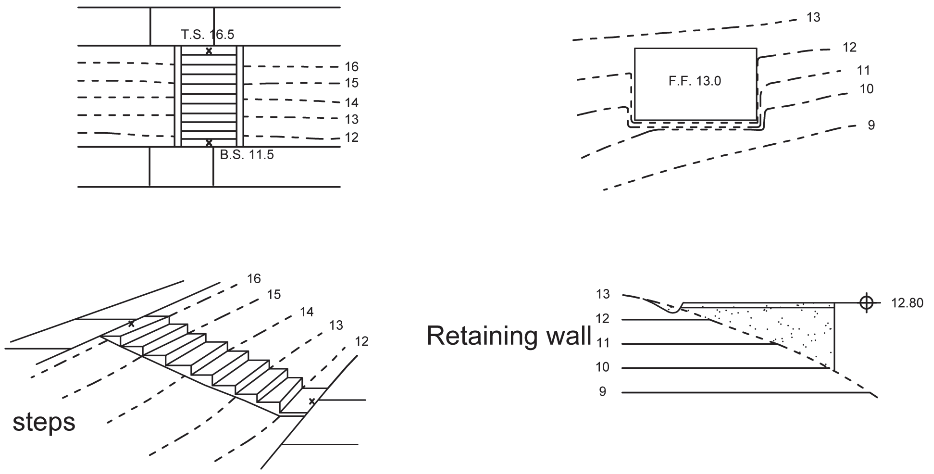


Figure 3.8 *Grading using steps and retaining wall*

5. A drainage swale that can direct the water flow of the slope. This can be located near any structure such as a building, a sports ground, or a parking lot (Figure 3.9).

3.8 Grading procedures

Grading can be done as follows:

1. Specify the spots and the size of the area to be graded.
2. Decide which approach is suitable for that area.
3. Determine a suitable finish grade in line with the approach.
4. Specify the new slope after grading based on the type of soil and its stability.
5. The meeting grade of the new graded area should not be too wide.

The number assigned to the new slope should be a half of the number of the contour interval such as 7.5 or 18.5 if contour interval is 1 meter, while the number assigned to the 0.5 meters interval slope should be 27.25 or 28.75. This will make calculation of the new contour easier. The slope of the new knoll depends on the soil consistency or soil texture.

The meeting grade indicates the point where the slope of the new grading ends. The earth work done by the contractor ends there too. In the plan, the meeting point of the contour and the proposed contour must be clearly specified. The landscape architect should try to minimize the amount of grading by making the meeting grade the shortest possible in order to reduce costs and disturb the natural setting the least.

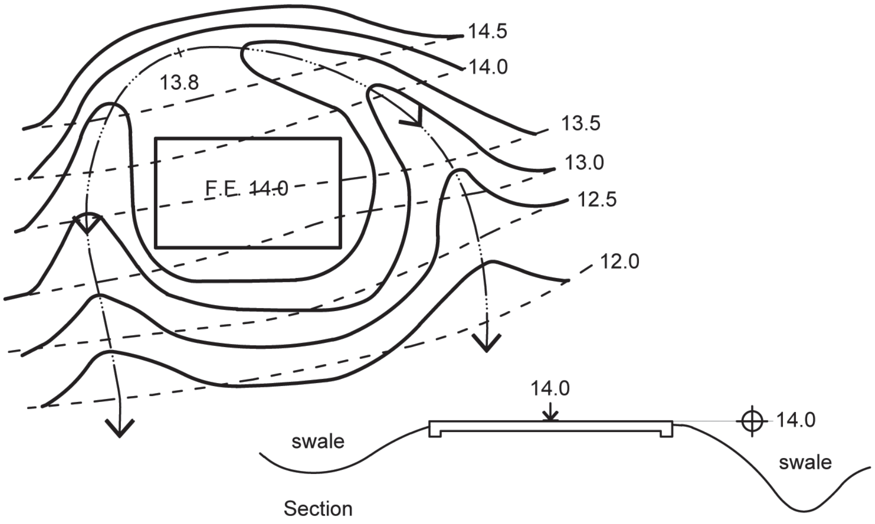


Figure 3.9 *Grading using shallow swale draining water around a plain whose finish elevation is 14.0 m.*

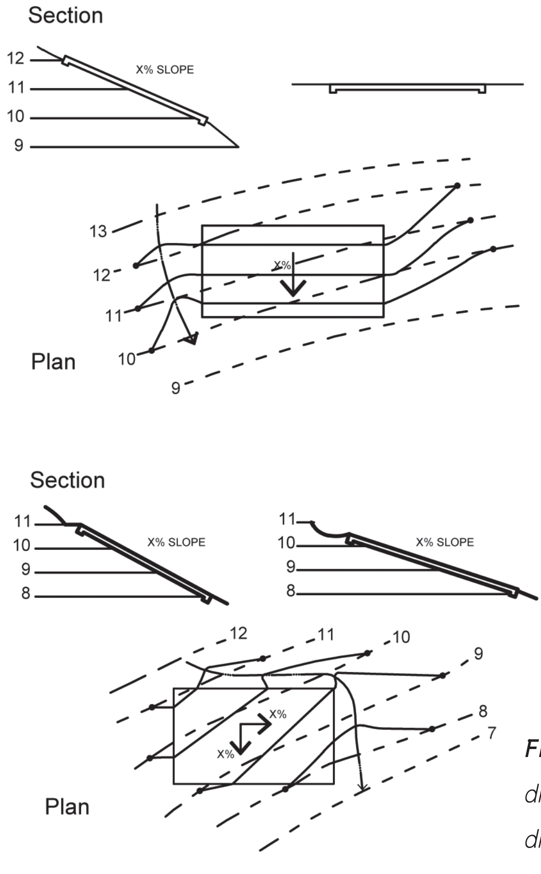


Figure 3.10 *Grading by locating a swale and directing the runoff on the uniform slope to one direction (top) and to two directions (bottom)*

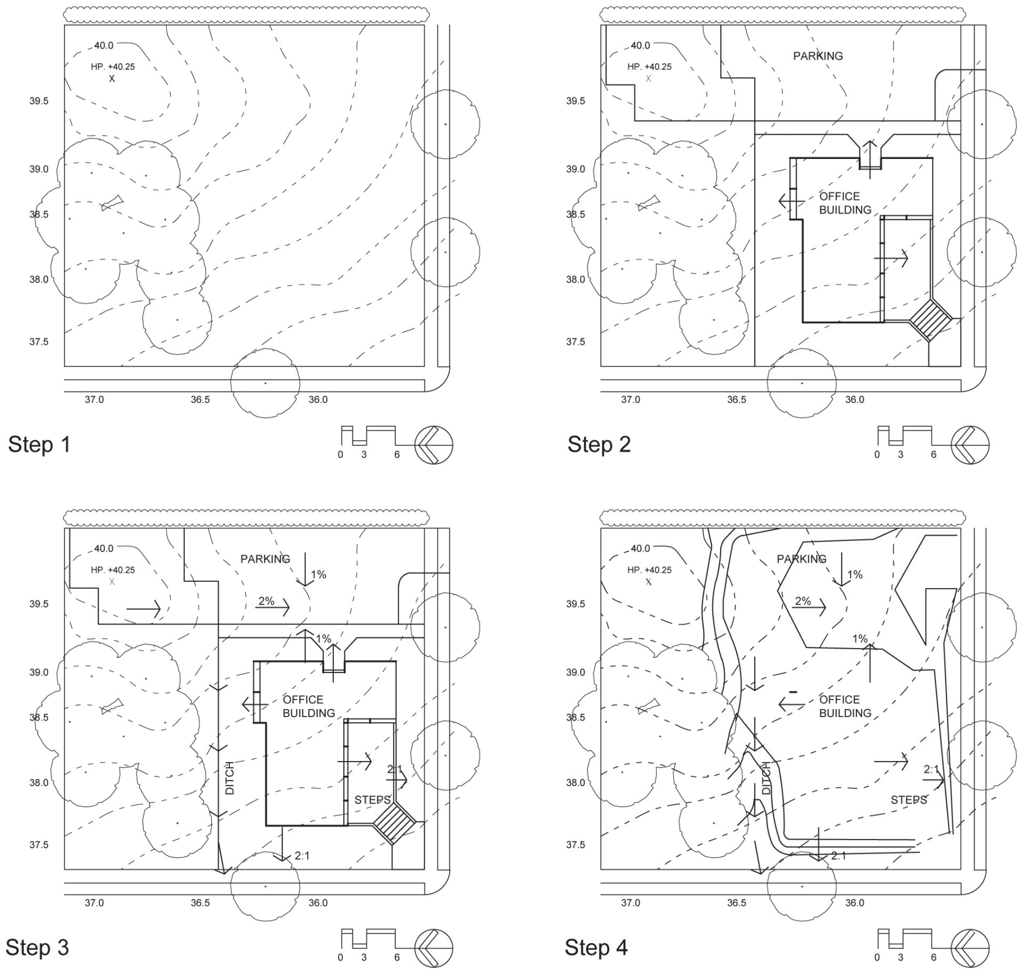


Figure 3.11 *An example of a process in designing a site planning and layout of grading for drainage*

Step 1 A contour plan and the existing trees

Step 2 A plan that retains as many existing trees as possible

Step 3 Planning drainage by assigning the slope, drainage direction, and the sizes of drainage swales

Step 4 Grading

3.9 Factors affecting grading plan

In grading, landscape architects have first to understand the process of grading and after that they have to study the constraints and design approaches that are suitable for the site including drainage and aesthetics. Factors to be taken into consideration are:

1. **Existing vegetation**. Most existing vegetation has to be preserved. If a tree has to be removed or transferred to another place, its characteristics (form, size, providing shade, bearing flowers or fruits, and maturity, replacement cost and the effect of the tree on the plan have to be considered. In addition, a change in landform also affects the growth of the existing vegetation; as a result, the architects have to consider the level of the ground water, the distance from the drainage, the soil type and the new structures.

   Landscape architectures have to be aware that big trees affect people's feelings so much that an organization in Thailand called "Big Trees" has been set up to campaign against tree cutting especially in construction sites.

2. **Existing surroundings and landform**. Whether to change the landform and how much change should be made depends on the architect's decision; however, the change has to blend in with the surroundings and must not affect public utilities.

3. **Neighboring areas**. These have to be kept intact. The drainage system of the site, in particular, must not affect the neighboring areas.

4. **Engineering processes**. The existing drainage should be disturbed the least and the new drainage must take into account the existing surroundings especially city drainage systems. Public drainage systems, public utilities both above and under ground must not be affected as it could lead to damages and unnecessary costs.

5. **Geology**. Rocky outcrops, high underground water level, types of soil that pose difficulty for grading such as marsh land require special grading

techniques. For example, special grading techniques were used to build Suvannabhumi Airport, located on low ground with soft soil and this cost a large amount of money. The airport also runs a risk of sinking in the future (see details in Chapter 5: Site Problems and Land Improvement).

Grading to make an open surface pavement

In an open surface, a slope has to be calculated for drainage and the contour line is drawn pass the surface. The angle of the slope depends on the activities, vehicles and the materials covering the surface. The materials affect the velocity of the water runoff.

The type of soil determines the rate of erosion. Soil erosion and slope are closely related. Soil erosion occurs when the slope is more than 2% of the level. However, if the soil is loose, 1% of the slope can cause soil erosion; as a result, to prevent soil erosion, groundcover such as grass or covering materials such as gravel, concrete or wire mesh are required.

Size of slope for open surface		
	maximum (%)	minimum not less than (%)
Road	8	0.5
Parking lot	5	0.5
Service space	5	0.5
Main entrance building	4	1
Space befor entrance	2	1
Main walkway	8	1
Ramp	10	1
Lawn	3	2
Swale	10	2
Grass mound that use lawnmower to cut	30	

3.10 Adjustment of road alignment

The assumption is that people and vehicles can travel two ways – horizontally and vertically. At the horizontal level, they go from one place to another while at the vertical level, they cross over something. Horizontal movement requires less energy than the vertical movement because it does not have to fight gravity.

In general, the slope slows both people and vehicles; as a result, the road has to be horizontal as much as possible through cutting, filling and cut and fill. In reality, However, the road connect alurays be built on level ground so we have to find ways to manage we can either make the route slope slightly all the way or make it horizontal most of the way and apply a short distance using ramp.

One approach to road alignment is following the contour with a slight tilt. This approach makes the road level off but a lot of grading is required to make the road surface wide enough for travelling. Another is building the road vertically against the contour and this approach requires very little grading but the road is very steep. Walking up this kind of road is very tiring and driving up this road is very difficult. Some kinds of vehicle cannot go along this road and it could cause road accidents.

Of the two approaches, if we want to travel across a hill or mountain as quickly as possible, the second approach is the best option, but if we want to travel more easily, the first is the best. In practice, both are combined to build roads to facilitate all kinds of vehicles.

Grading for routes built on the plain is easily done by making road surface even and spacing the distance of the contour lines equally. A walkway can be uneven as people may like to walk on this but uneven ground is unsuitable for vehicles because they have to slow down frequently, wasting fuel and could lead to accidents. Drainage is also an important part of the alignment. As for the plain,

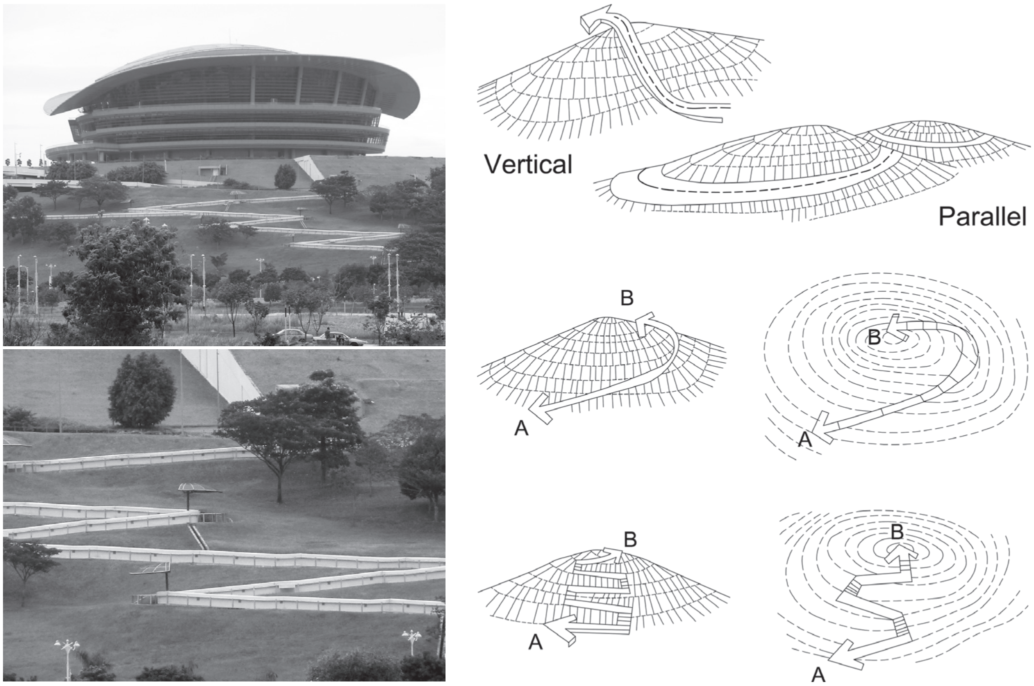


Figure 3.12 *The walkway to the entrance of Putrajaya International Convention Center (PICC) located on a hill. It integrates grading approaches to make the walkway come to the center. It zigzags along the contour.*

a high point or a low point has to be identified for drainage purposes, which can be done by contour grading, the spot elevation, or represented by a cross section or a profile.

Road alignment is done in the same way as grading the plain, in that the proposed contour line has to be separated from the existing contour at the proposed meeting point and turned to the existing point, but at the lower level if filling is an option and at the higher level if cutting is an option. The new contour line has to meet the existing contour line again when grading is finished.

Vertical road alignment is done by a gradual rise along the length of the slope and this is the foundation of the road system, so called manipulating the contour lines. This is considered both a science and an art, leading to a suitable, pleasant, cost-effective and multi-purposeful road. However, the first thing to know before grading is done is the highest point of the slope and the width of the road.

The slope of the road depends on the type of vehicle. For example, the best slope for a passenger car is not more than 10% while that for a pedestrian walking a long distance is about 3-5% but a short distance can be about 12-15% or even about 30%. In practice, the government office is responsible for deternening the slope rate of the roads such as the maximum slope of a road and the maximum slope of a road up a parking garage and the slope for pedestrians, creating a universal design that facilitates the general public, children, the elderly and the handicapped (with wheelchairs) to access a building.

The width of the road depends on the existing size of the land, the speed of traffic, the amount of traffic, safety, scenery and ecology. The width of the road where the slope is steep or where the scenery is beautiful should be as narrow as possible because a narrow road reduces cutting or filling, leading to a reduction in damaging the beautiful scenery or fragile environment. In general, the slope should be avoided in road alignment; for example, the road should follow the basin rather than the slope or follow the river rather than the hill ledge. To save costs, the road should be aligned along the base of the ledge. All in all, a suitable road alignment should preserve the environment as much as possible and make the road blend in with it.

Things to consider when road alignment is carried out:

The slope of the road mentioned above is suitable for traffic, reasonably priced and safe. At a low gear, a vehicle can climb uphill with a slope of 17%; therefore, 17% is the maximum slope for a bridge, up or down a parking lot, an entrance to a highway and minor roads. A slope for major roads or highways should not be too steep because it is costly and dangerous (a normal slope is from 4-8%). However, a slope that is higher than this can be found in old roads or in hills or mountains. In the United States, the highest slopes of highways are

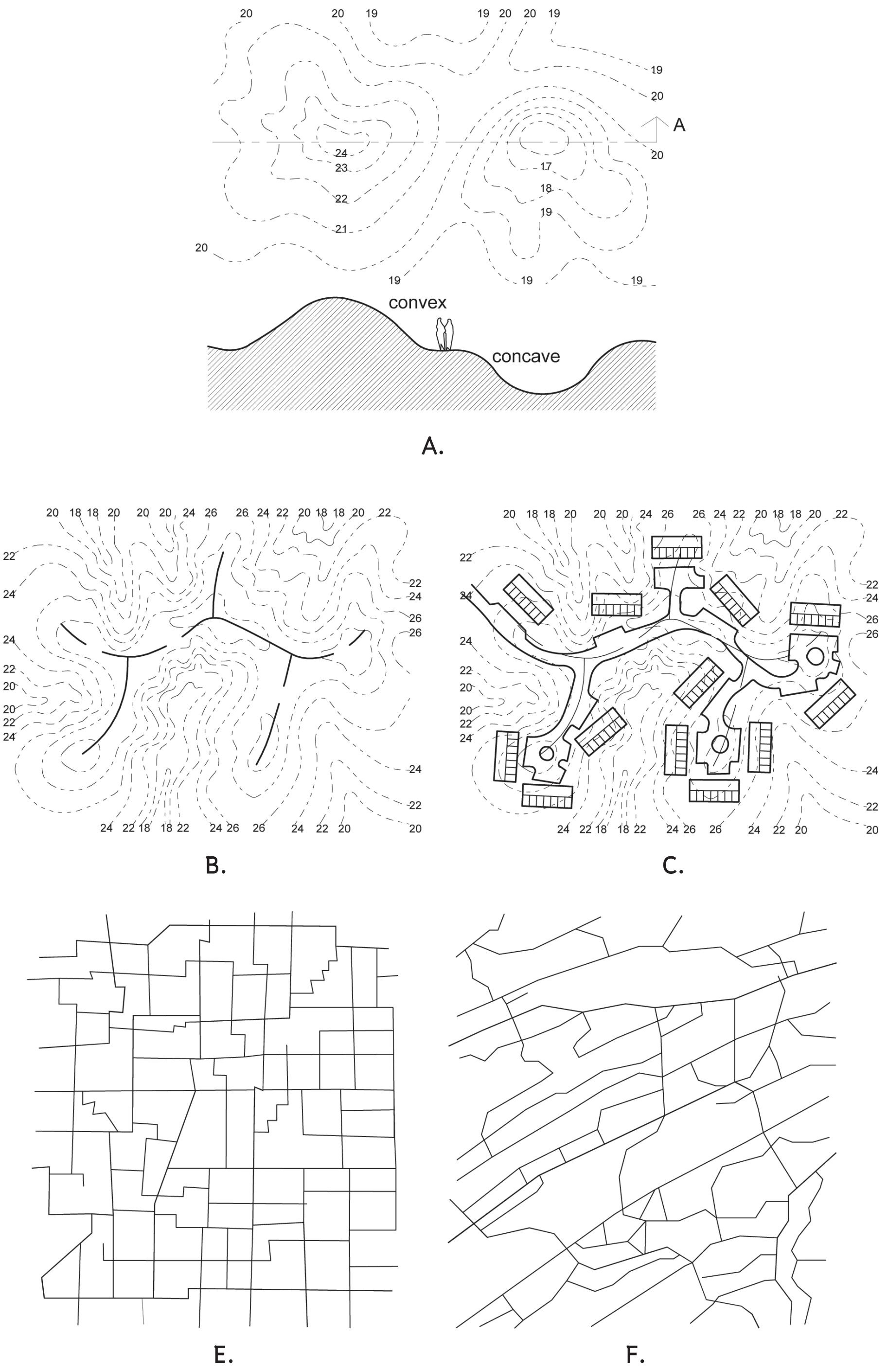


Figure 3.13 *The contour map related to concave and convex hills cross section (A). The driveway on the plain is straight (E) but as for the hilly terrain, a suitable slope has to be graded; as a result, the road is winding (B, C, F).*

9-12%, while those of city roads are 30-32%. The slopes for structures or activity grounds along the roads should be as follows:

Side slope	With traffic	Highest 10%	Lowest 0.5%	Normal 1-3%
Back slope	With traffic	Highest 15%	Lowest 0.5%	Normal 1-5%
Side slope	Without traffic	Highest 15%	Lowest 0.5%	Normal 1-10%
Back slope	Without traffic	Highest 20%	Lowest 0.5%	Normal 1-10%

As for civil engineering, road alignment focuses on concerns to do with traffic engineering which differ from those of landscape architecture. This chapter presents basic traffic engineering which is related to landscape architecture so that landscape architects can design road alignment in line with traffic engineering which focuses on safety and traffic standards.

3.11 Basic road alignment

A large scale project, a highway landscape project, an urban landscape design, a national park design or a tourist attraction design are related to civil engineering – road alignment and traffic engineering. Road alignment is fundamental knowledge that landscape architects should know. This will help them in grading and designing road alignment or other functional areas as well as drainage. Civil engineers have to consider traffic volume, vehicle types/characteristics and speed when designing standardized road alignment.

Technical engineering terms that landscape architects should know are:

1. Horizontal alignment
2. Vertical alignment
3. Super elevation

As for road alignment, horizontal alignment has to be in line with vertical alignment and to help vehicles follow the curve or bend safely, the bend has to be raised (tilting the road by raising the outer side of the road).

3.11.1 Horizontal alignment is important because it helps traffic to go smoothly and safely. Drivers can accelerate at the required speed. This alignment depends on the systematic calculation of four patterns:

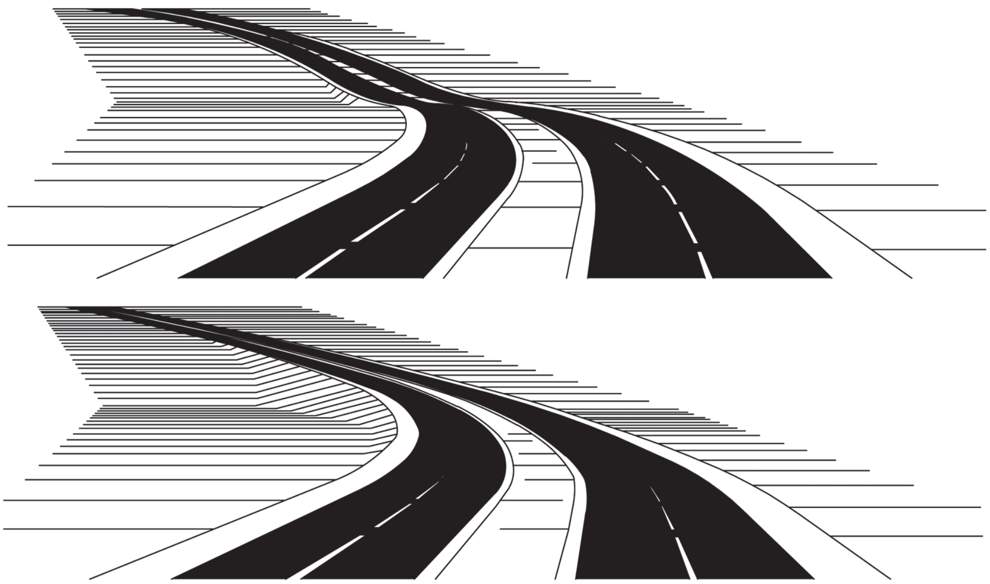
Pattern 1 : Tangent

Pattern 2 : Curve

Pattern 3 : Tangent to circular curve

Pattern 4 : Tangent to spiral curve to circular curve

Each pattern focuses on different kinds of driving safety. The tangent to spiral curve to circular curve facilitates the turning of the wheel. The distance between points and reference points are specific. Important points and reference distances include R (Radius of circular curve), BC (Beginning of curve) or PC (Point of Curvature), EC (End of curve) or PT (Point of tangency), PI (Point



Source: *Norman W. Garrick, Geometric Design of Transportation Facilities*

Figure 3.14 *Horizontal alignment in line with vertical alignment in a steep landform will make driving safer. The above Figure shows a change in horizontal alignment whenever there is a change in vertical alignment. Although they are in line with each other, the blind spot is wider than the horizontal alignment that slope gently all the length of the road (in below Figure)* of intersection), T (Tangent length), L (Length of curvature), M (Middle ordinate), E (External distance), C (Chord length) and D (Deflection angle).

The length of each part can be calculated by

T (Tangent length) = PI – BC = EC – PI

L (Length of curvature) = EC – BC

L (Length of spiral) = $L = (0.0702\ V^3)/RC$

When L = minimum length of spiral (m)

V = speed (kph)

R = curve radius (m)

C = rate of increase in centripetal acceleration (m/s^3)

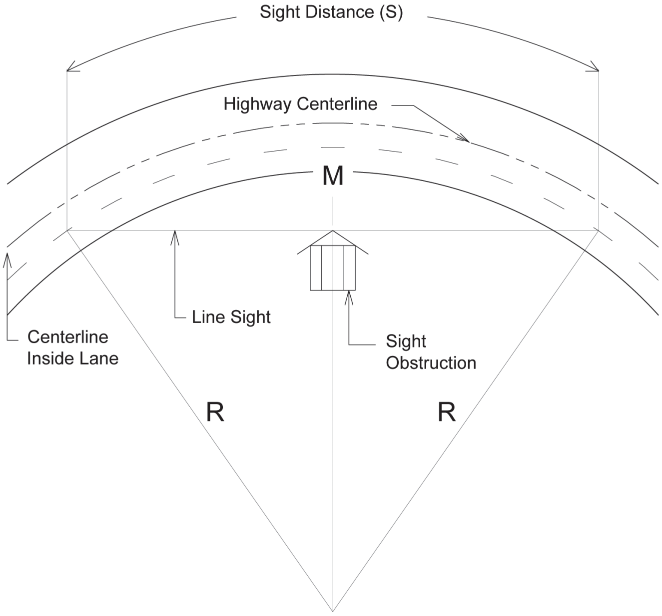
The above formula differentiates the circular curve and the spiral curve in that the spiral curve does not have a specific center. The spiral curve stems from the calculation of parabola.

3.11.2 Vertical alignment is used when the landform is hilly and the design has to blend in with the landform even though grading is done. Traffic engineering affects the curves, the slopes and the distance between the slopes so that driving is safe.

There are two types of vertical alignment: crest vertical curve and sag vertical curve. The former deals with passing sight distance (PSD) – the distance a vehicle uses to take over another and return to the driving lane safely while the latter deals with stopping sight distance and is related to headlight beams at night. When the slope of a crest vertical curve or that of a sag vertical curve is too steep, an accident can happen since the stopping sight distance becomes short so the driver cannot stop the vehicle in time (see Figure 3.15).

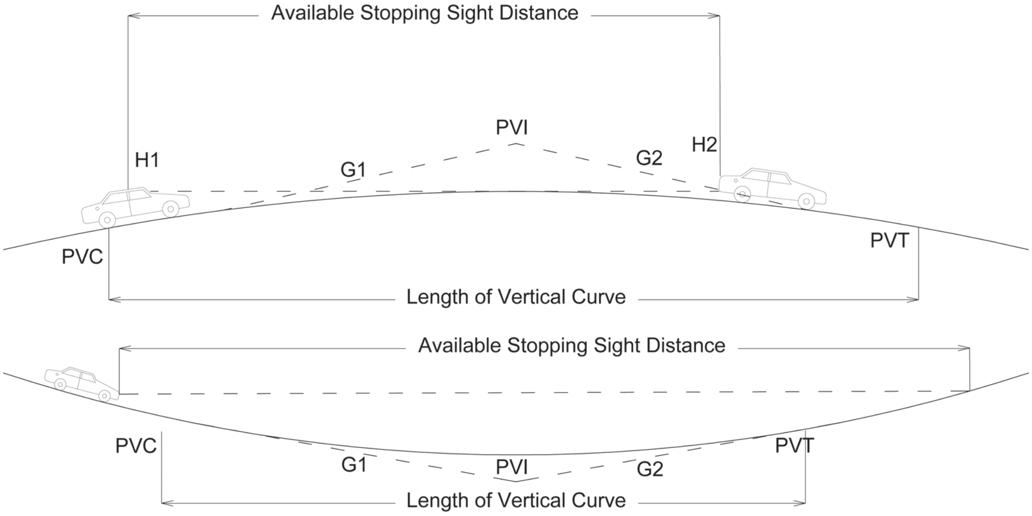
3.11.3 Elevation is slanting the road by raising the outer rim of the road so that the weight of the vehicle can keep the vehicle on the road when going along the curve. The elevation that changes from a normal crown to full super elevation can make driving along the curve smooth. This change is called transition length.

Source: *Autovia olivar. Wikimedia Commons. User: Gestion. Inf. And.*



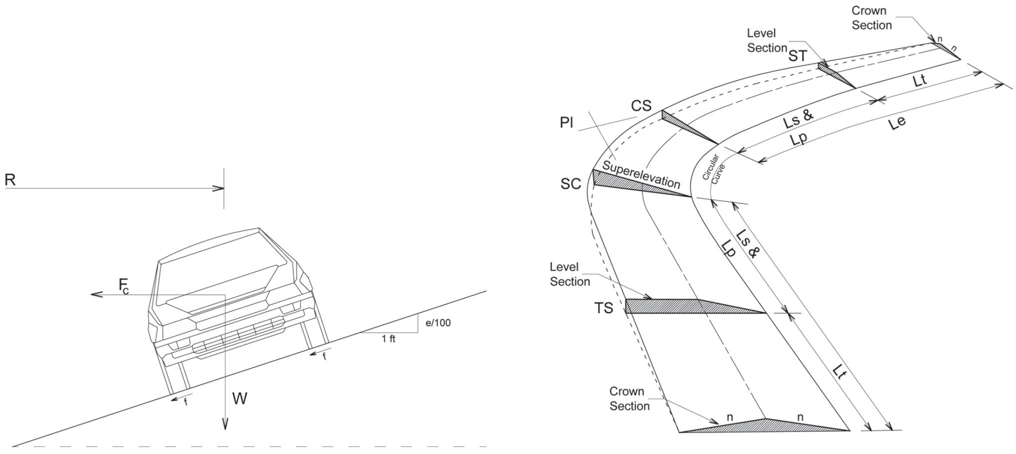
Source: *AASHTO, 2004. A Policy on Geometric Design of Highways and Streets.*

Figure 3.15 *Autova del Olivar, road in Spain uses. vertical road alignment to make driving safe and pleasant.*



Source: *FHWA U.S. Department of Transportation. 2009. Speed Concepts: Informational Guide*

Figure 3.16 *Vertical alignment for both uphill and downhill has to consider sight distance for safe driving at night.*



Source: *FHWA U.S. Department of Transportation. 2009. Speed Concepts: Informational Guide/ Austroads. 2009. Guide to Road Design*

Figure 3.17 *Super elevation countering centrifugal force when a speeding vehicle enters the curve Placom KP90N N-Series Roller-Type Digital Planimeter*

3.12 Earth work calculation

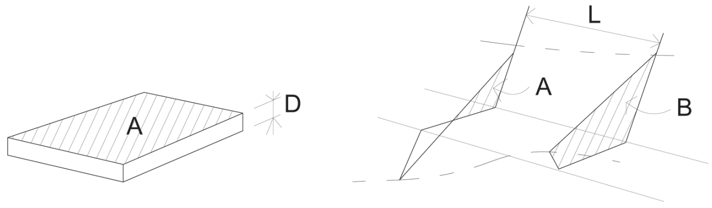
In grading if the amount of earth from cutting and filling is about the same, it can save budget and is easy to construct. Earth work calculation is necessary and can be done as follows:

Approach 1: Spot levels

Approach 2: Grid

Approach 3: Average end method

Approach 4: Contours



Volume = Area x Depth

$$\text{Volume} = \text{Average Area} \times L = \frac{A + B}{2} \times L$$

Primary principle

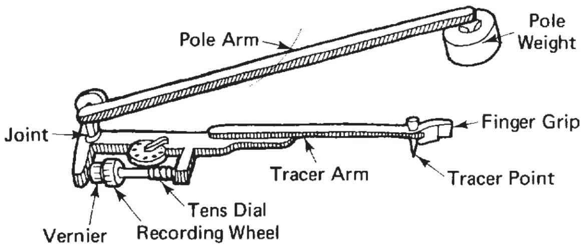
1. From the contour, volume = area x depth
2. From the cross section, average volume = average area x length

The area to be multiplied by height to obtain volume can be calculated by:

1. a simple measurement based on the area formula for a triangle or a square.
2. graph overlay by using a square sheet and calculating the area by counting the number of squares.
3. a planimeter – both digital and analog (polar) types.

4. area command in CAD Program when the design is done by computer.

Placom KP90N N-Series Roller-Type Digital Planimeter



Polar Planimeter

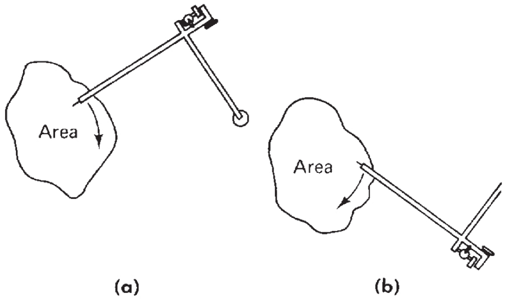
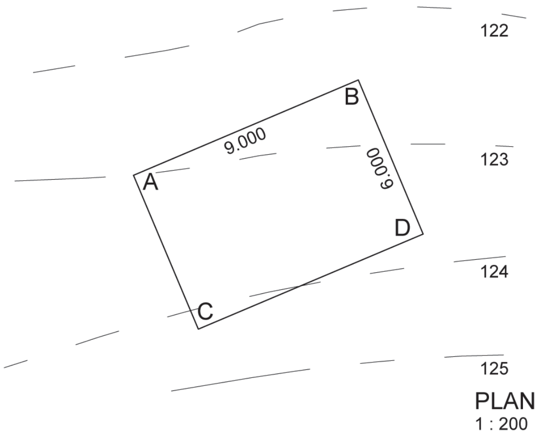


Figure 3.18 *Digital Planimeter and Polar Planimeter can measure an area and the length of the line.*

Calculation of earthwork 1. using (spot levels)

Spot levels are suitable for a small sites with uniform slopes. This calculation is based on the principle of prisms.



For example, the grading of area ABCD and the FF = 122.00. The margin is cut vertically.

Calculate the existing levels A, B, C, D

A = 123.00

B = 122.50

C = 124.30

D = 123.80

Calculate the depth of the proposed levels

A = 123.00 – 122.00 = 1.00

B = 122.50 – 122.00 = 0.50

C = 124.30 – 122.00 = 2.30

D = 123.80 – 122.00 = 1.80

Total = 1.00 + 0.50 + 2.30 + 1.80 = 5.60

Average = 5.60/4 = 1.40

Volume = area x depth

= (9 x 6) x 1.40

= **75.6 m^3**

Calculation of earthwork 2. Using (Grid)

A grid is suitable for a larger site with a non-uniform slope.

The site is divided into small squares and the area of each square is calculated by multiplying the depth of each small square.

The new level = 120 meters.

The site is divided equally into small squares (if it is not a square, the calculation is done separately). In this case, the square is 3 x 3 and the angle of

- a shares with 1 small square
- b shares with 2 small squares
- c shares with 3 small squares
- d shares with 4 small squares

Formula for volume

$$= \text{area of a small square} \times \frac{[(\text{total a}) + (2 \times \text{total b}) + (3 \times \text{total c}) + (4 \times \text{total d})]}{4}$$

$a = 4.2 + 3.3 + 4.9 + 6.5 + 6.9 = 25.8$

$b = 4.0 + 3.8 + 3.7 + 3.5 + 3.9 + 5.1 + 6.7 + 6.8 + 5.8 + 4.9 = 48.2$

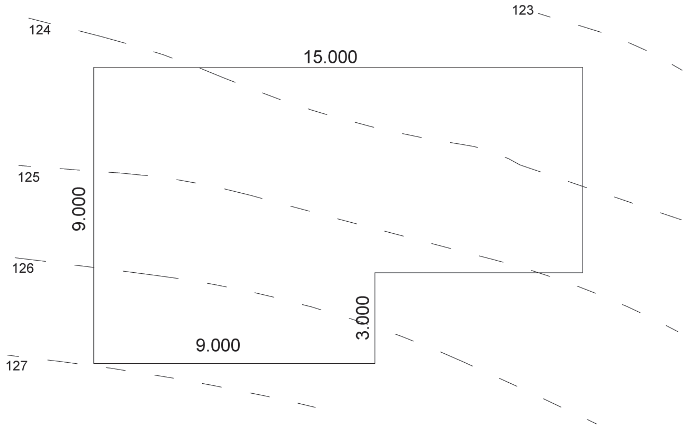
$c = 5.3 = 5.3$

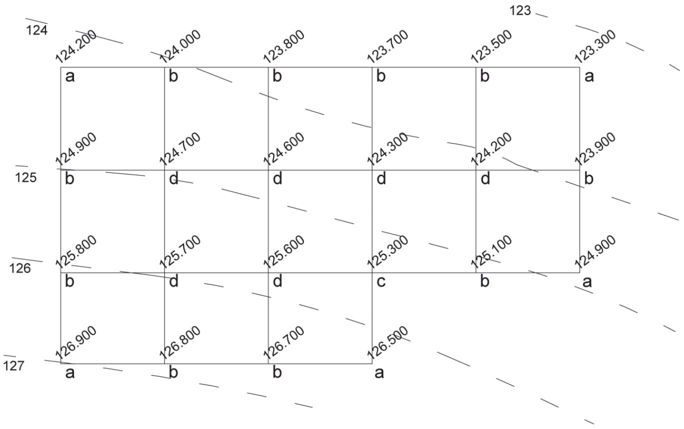
$d = 4.7 + 4.6 + 4.3 + 4.2 + 5.6 + 5.7 = 9.1$

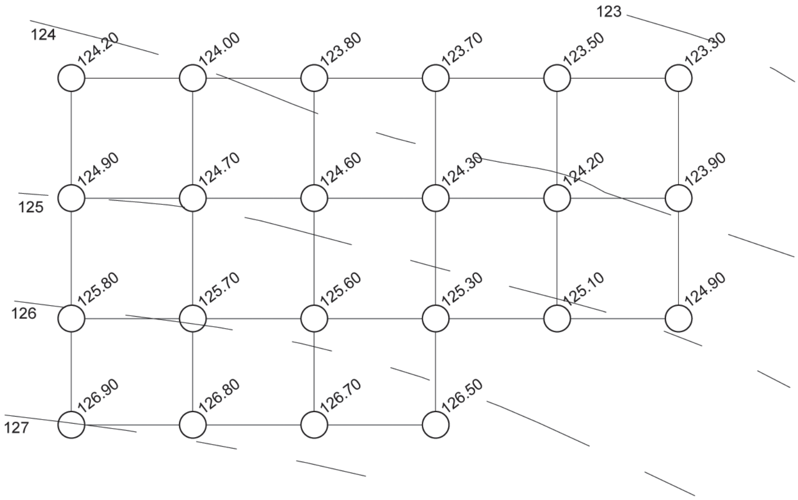
$$\text{Volume} = \frac{(3 \times 3) \times (25.8) + (2 \times 48.2) + (3 \times 5.3) + (4 \times 29.1)}{4}$$

$$= 9 \times 63.6$$

$$= \mathbf{572.4\ m^3}$$





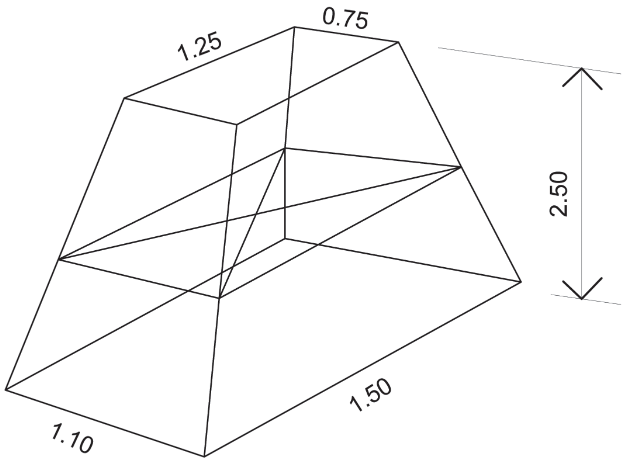


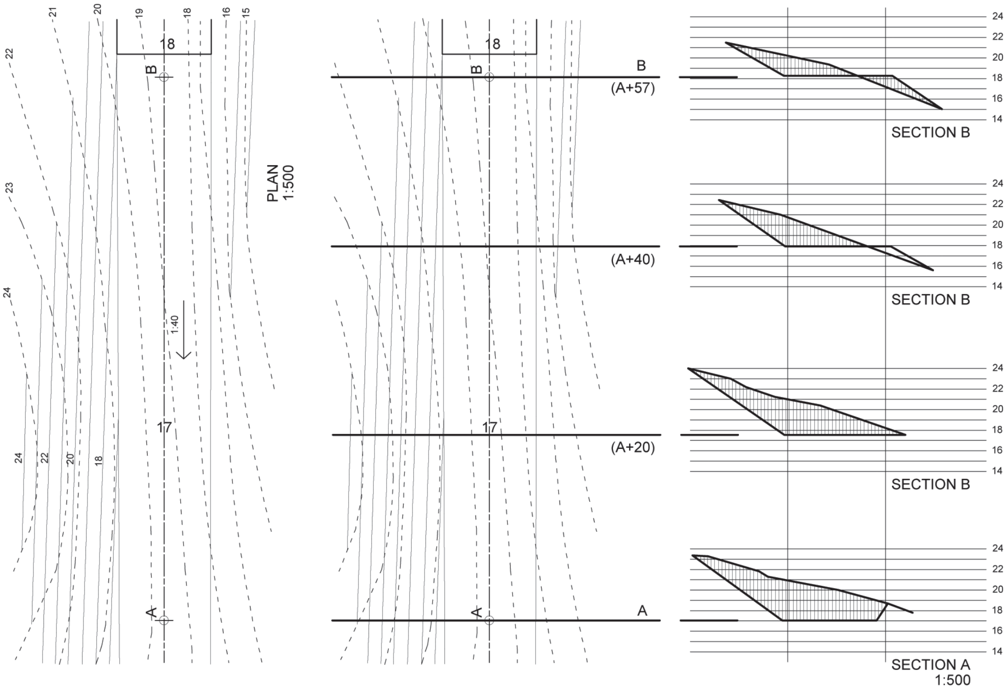
Calculation of earthwork 3. Using (Average end Method)

The average end method is used to calculate the earth work from many cross section Figures based on the principles of prism whose plains are parallel.

$$\text{Volume} = \frac{\text{plain 1} + \text{plain 2}}{2} \times \text{height}$$

It is an easy and popular approach but the result is greater than the reality. This is suitable for the calculation of the cross section of the road.





Cut/fill calculations (average and method)							
crosss-section	cut m²		fill m²		distance	volumes m³	
	section	average	section	average			
A	48		0				
		45			20	200	
A + 20	42		0				
		33		3	20	660	60
A + 40	24		6				
		17		7	17	289	119
B	10		8				
						1849	179

Figure 3.19 *Steps and table showing earth work calculation (Average End Method)*

Calculation of earthwork 4. Using (Contours)

Contours are another easy and popular approach because sections are not required and this is suitable for non-uniform grading.

Simple formula

Volume = Interval x (area 1 + area 2 + area 3 + ...)

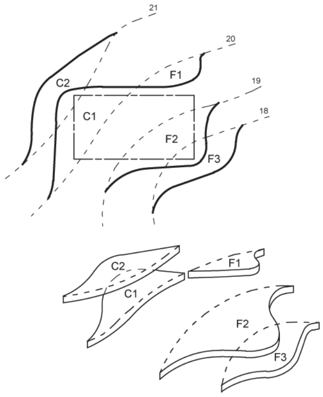
The above formula is a rough calculation. A precise calculation can be done by using an adjusted area contour method as follows:

Volume of filled earth =

Interval $\{^5/_6 F1 + F2 + F3 + ... + ^5/_6 Fx\}$

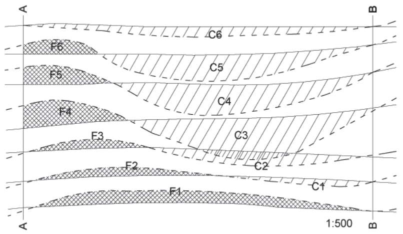
Volume of dug earth =

Interval $\{^5/_6 C1 + C2 + C3 + ... + ^5/_6 Cx\}$



Filled earth is represented by F (Fill)

Cut earth is represented by C (Cut)



Cut/fill calculations - Contour Method							
contour level	cut m²		fill m²		contour interval	volume m³	
	no.	adjusted area	no.	adjusted area		cut	fill

Cut/fill calculations - Contour Method							
contour level	cut m²		fill m²		contour interval	volume m³	
	no.	adjusted area	no.	adjusted area		cut	fill
20	-		F1	$\frac{5}{6}$ F1			
22	C1	$\frac{5}{6}$ C1	F2	F2			
24	C2	C2					
					2		
	C5	C5	F5	F5			
32	C6	$\frac{5}{6}$ C6	F6	$\frac{5}{6}$ F6			

Figure 3.20 *Steps and table showing earth work calculation (Contours Method)*

Bulking Factors

The bulking factor is the amount of dug earth that is usually more than the estimated amount. This depends on the type of earth. If the earth is coarse/gravel, the bulking factor is higher than that of fine earth. In general, the bulking factor is 10%.

– As for the earth to be carried away, the calculation is 130% of the dug earth

– As for the earth to be filled, the calculation is 110% of the filled earth

Question concerning calculating the bulking factor

A truck with 10 cubic meters has to carry earth away from a site. It is estimated that the volume of cut earth is 1500 cubic meters and the filled earth is 1232 cubic meters.

use 10% in case of filling.

1232	=	110% x volume of earth to be filled
Volume of earth to be filled	=	1232/1.10 = 1120 cubic meters
The remaining earth	=	1500 – 1120 = 380 cubic meters

use 30% in case the earth is to be carried away

Volume of earth to be carried away	=	380 x 130% = 380 x 1.3 = 495 cubic meters
The truck has to make	=	495/10 = 49.5 = ~50 trips

3.13 Construction procedure

The steps of grading before construction are as follows:

1. Site preparation, clearing and demolition
2. Top soil stripping
3. Water detention, existing tree protection (from floods or soil compaction) and soil erosion prevention

4. Site marking indicates the truck to fill the earth and do rough grading or bulk excavation. The earth is piled up 0.20-0.30 meter. between each pile and graded roughly. The contour mapping is carried out by assigning distances, contours, areas to be cut/filled, amount of earth to be dug/filled based on the bulking factor.

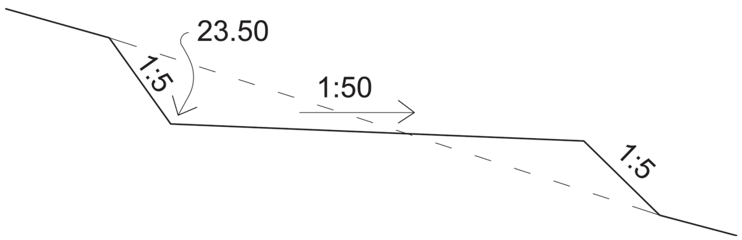
5. Assigning marks for structures and road alignment
6. Planning utilities and site systems
7. Finish grading or backfilling and fine grading as in the detail design
8. Surfacing

As concerns details, some items have to be more specific such as building a wall to prevent earth from sliding, additional grading to support the earth by using a geotextile or other materials to prevent the separation of newly filled earth from the existing earth when a load such as slab on ground, vehicles or people are pressed on the grading site, building an underground drainage system or using concrete that can absorb water. Good grading has to consider the volume of earth to be filled and the maximum use of an earth well.

3.14 Sample question

Calculation of platform grading

Question : Grade the terrace with 30.00 meters. x 30.00 meters. The uniform slope is 1 : 50 (D : L) from AB to CD. The slope of cut and filled earth is 1 : 5 (cross section). The edge contour line of AB is 23.50 meters. Find the edge contour line of CD.

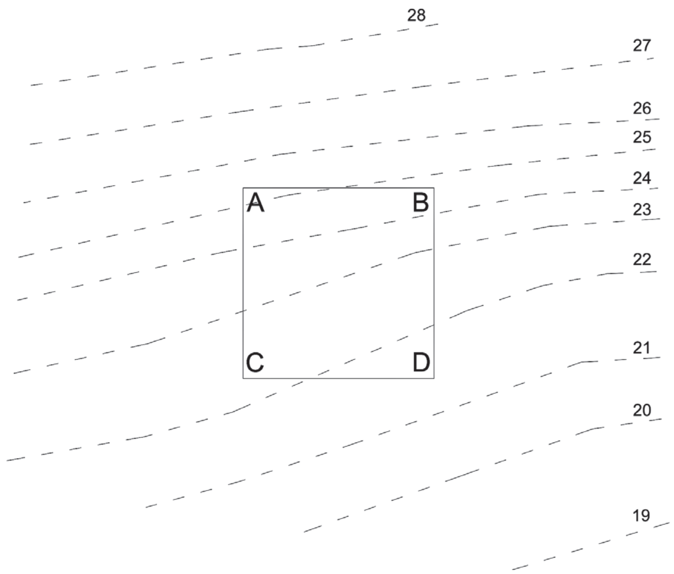


Answer

1. AB = 23.50 m., so we have to find the point on the contour line at 23.00 m.

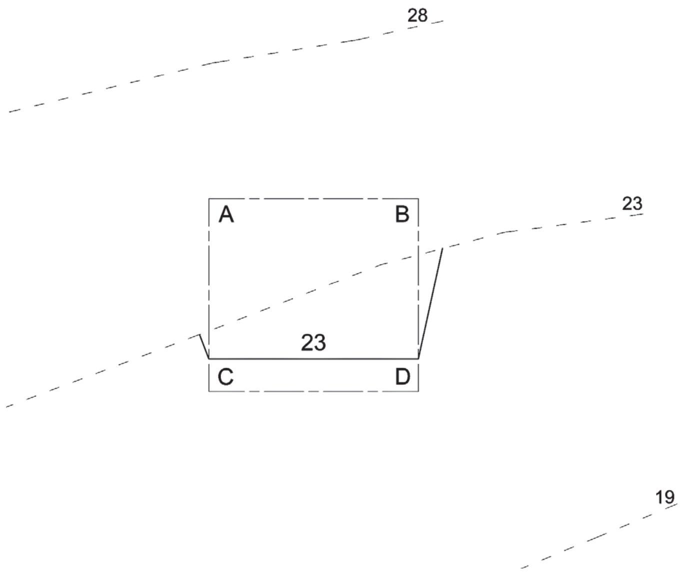
D	=	GL
23.50 – 23.00	=	1/50 x L
L	=	0.50 x 50
	=	25

The measurement from AB to CD is 25.00 meters. Draw a parallel line with AB to the contour line at 23.00 meters.



2. Find the contour line of CD

	D	=	GL
		=	1/50 x (30.00 – 25.00)
		=	1/50 x 5
		=	0.10
The contour of	CD	=	23.00 – 0.10
		=	22.90



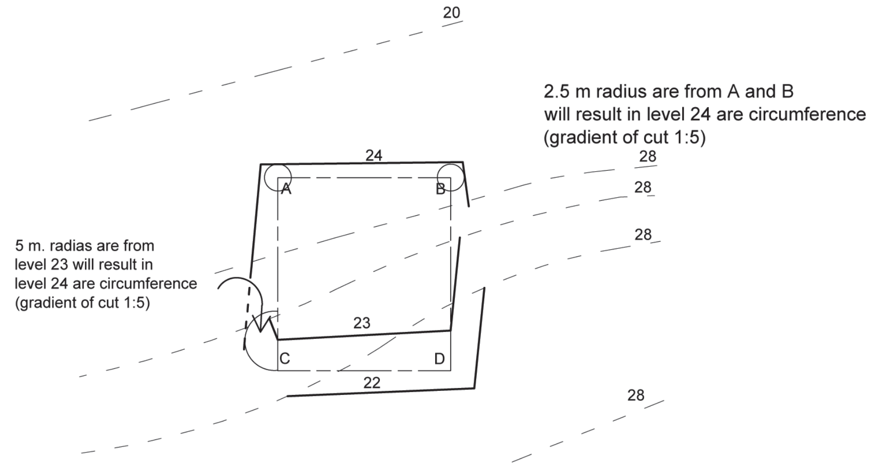
3. Find the line at 24.00 meters above AB by using the slope of cut and filled earth = 1.5

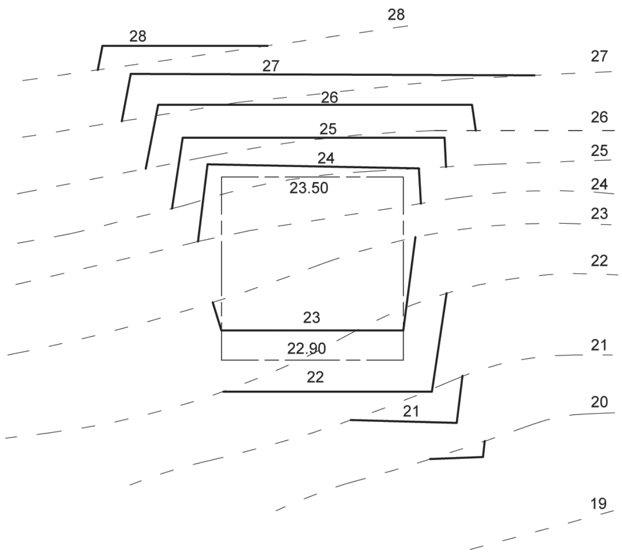
D	=	GL
24.00 – 23.50	=	1/5 x L
L	=	0.50 x 5
	=	2.50

Draw a line 24.00 above AB = 2.50 meters. and use dividers with the radius of 2.50 meters to draw a circle using A, B as the center to determine the line of 24.00 meters.

4. Find the distance 1 : 5 that the line of 23.00 meters crosses and find where contour line of 24.00 meters will be D = 1, L = 5 then in this case L = 5 too, using divider radius of 5.00 meters to identify the line 24 meters (as in to the Figure). Finding contous line at 22.00 meters below CD using the some method as finding contour line at 24.00 meters above AB.

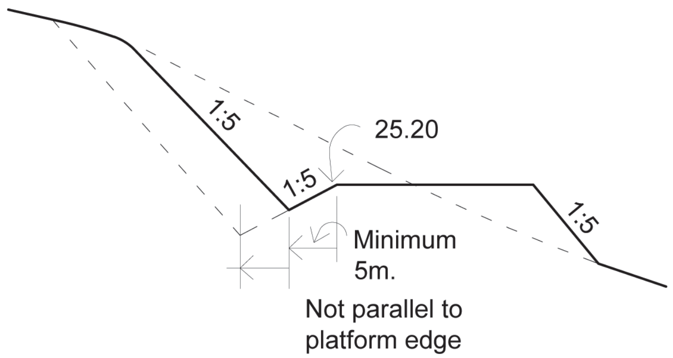
5. Adjust every affected line by assigning the slope of the cut and filled earth = 1.5 according to the Figure.





An example of the calculation grading of an open drainage swale

Question: Grading the terrace of 30.00 meters x 30.00 meters and the draining ditch by making the surface even at 25.20 meters The slope of the cut and filled earth is 1 : 5 (cross section). The distance from the terrace edge to the center of the open swale is at least 5.00 meters. The highest point of the swale contour is at least 5.00 meters from the terrace edge (according to the Figure). The slope along the swale = 1 : 50. (D : L)



Answer

1. The distance from the swale to the terrace edge = 5.00 meters. Draw a drafted 5.00 meters line along the swale around the terrace ABCD

2. The contour line of AB is 25.20 meters and the ratio of cut and filled earth is 1 : 5. The highest point (HP) of the swale is

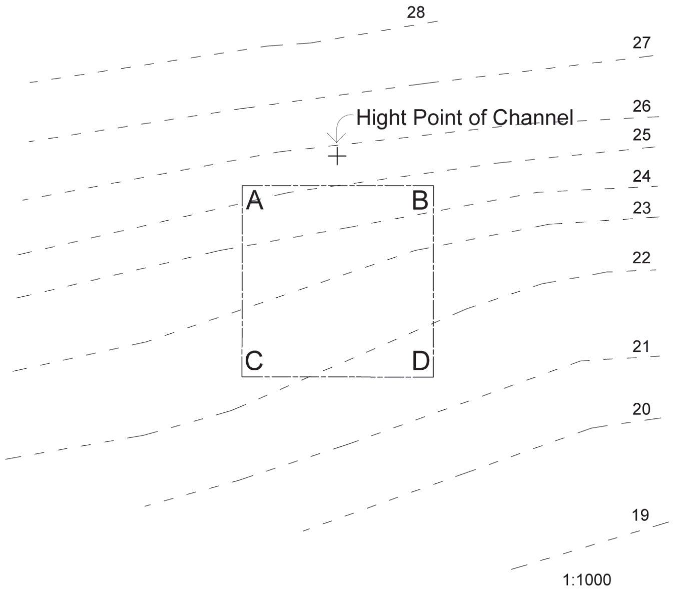
D = GL

= 1/5 x 5

= 1.00

HP = 25.20 – 1.00

= 24.20 meters



3. Point A, B is 25.20 meters The ratio of cut and filled earth is 1 : 5. Find the 25.00 meters line and the 24.00 meters line.

D 25.00 = GL

25.20 – 25.00 = 1/5 x L 25.00

L 25.00 = 0.20 x 5

= 1.00

The 25.00 meters line is 1.00 meters away from the edge.

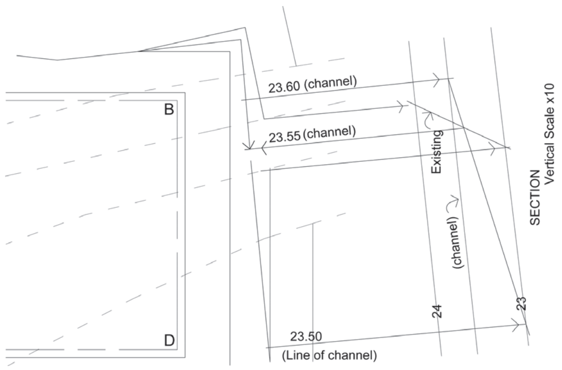
D 24.00 = GL

25.20 – 24.00 = 1/5 x L 24.00

L 24.00 = 1.20 x 5

= 6.00

The 24.00 meters line is 6.00 meters away from the edge. (or assume that 1 : 5, is 5.00 meters away from the 25.00 meters line that is in the same position.) Draw the 25.00 meters line and the 24.00 meters line as in the Figure.



4. Find the swale line from the H.P. when the slope of the swale is 1 : 50, with the contour lines of 24.00 meters, 23.00 meters, 22.00 meters, ... on the slope.

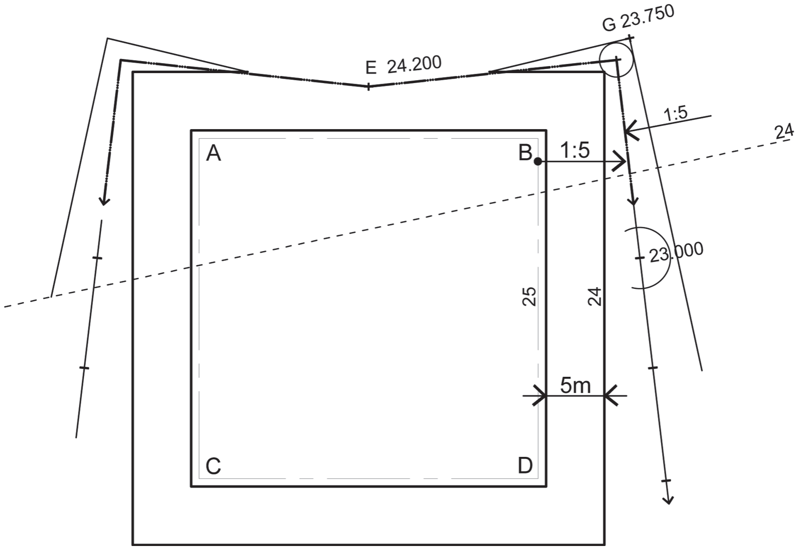
D 24.00 = GL

24.20 – 24.00 = 1/50 x L 24.00

L 24.00 = 0.20 x 50

= 1.00

The 24.00 meters line is 10.00 meters. away from the H.P.



The ditch line is slanted from the drafted line to obtain the assigned slope. HP is the center and the radius is 10.00 meters. Draw a circle to intersect the 24.00 meters line from item 3 as in the Figure.

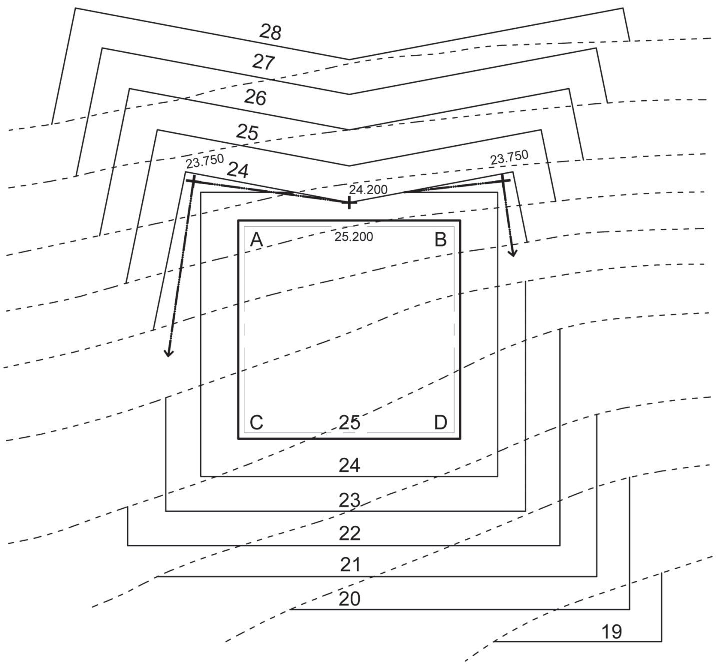
5. From the terrace corner, points A and B, draw a drafted line with an angle of 45 degrees, to find the sharp curve of the ditch. Find the contour along the drafted line with a sharp curve (L = 22.50 meters)

$$D = GL$$
$$= 1/50 \times 22.50$$
$$= 0.45$$

The contour line of the sharp curve is

$$24.20 - 0.45 = 23.75 \text{ meters}$$

6. Assign the mid-points of the contour of the ditch based on the sharp curve whose slope = 1 : 50 and adjust the grading as in the Figure.



An example of the grading calculation of road alignment and walkway

Question: Grade the road surface and the walkway. The width of the road is 7.00 meters and the slope lengthwise is not more than 8%. Adjust the crown to 2%, the cross slope of the lawn for drainage to 2%, the slope of the walkway to the lawn 1% and the height of the walkway edge 0.15 meters.

Answer

1. The contour line of the mid-point of the entrance is 1.50 meters. Measure if the contour line where the mid-point of the road intersects the 0.30 meters line (A) is more than 8%. Measure the distance of L from the distance between 2 points and the measurement is 56.00 meters.

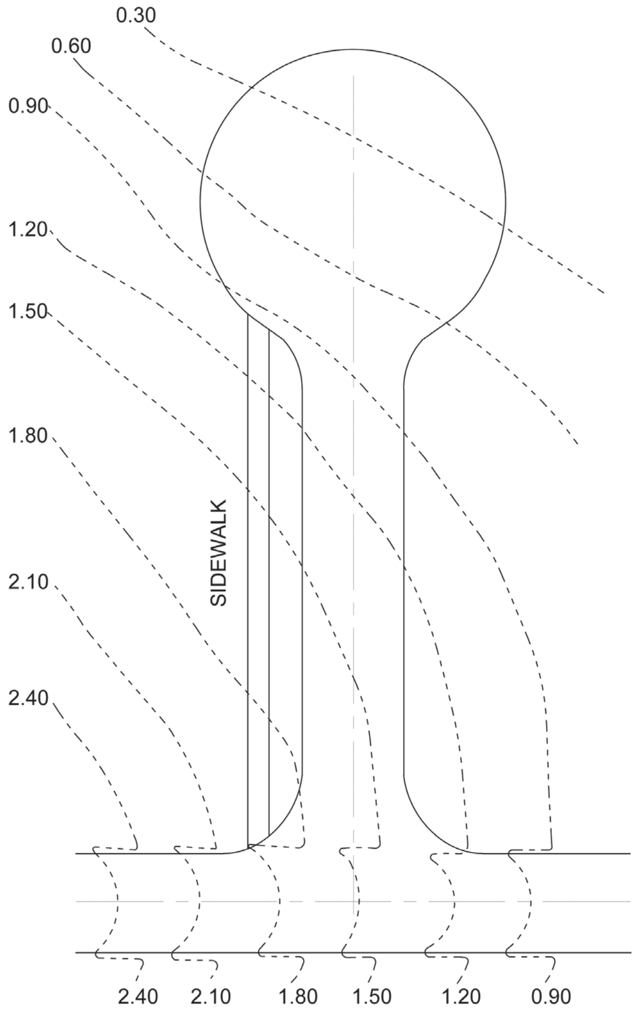
$$D = GL$$

$$1.50 - 0.30 = G \times 56$$

$$G = 1.20/56$$

$$= 0.0214$$

The slope = 2.14% (not more than 8%)



2. Find the points where the lines of 1.20 meters, 0.90 meters, and 0.60 meters intersect. The slope is 2.14% from item 1.

$$D = GL$$

$$1.50 - 1.20 = 0.0214 \times L$$

$$L = 0.3/0.0214$$

$$= 14.02$$

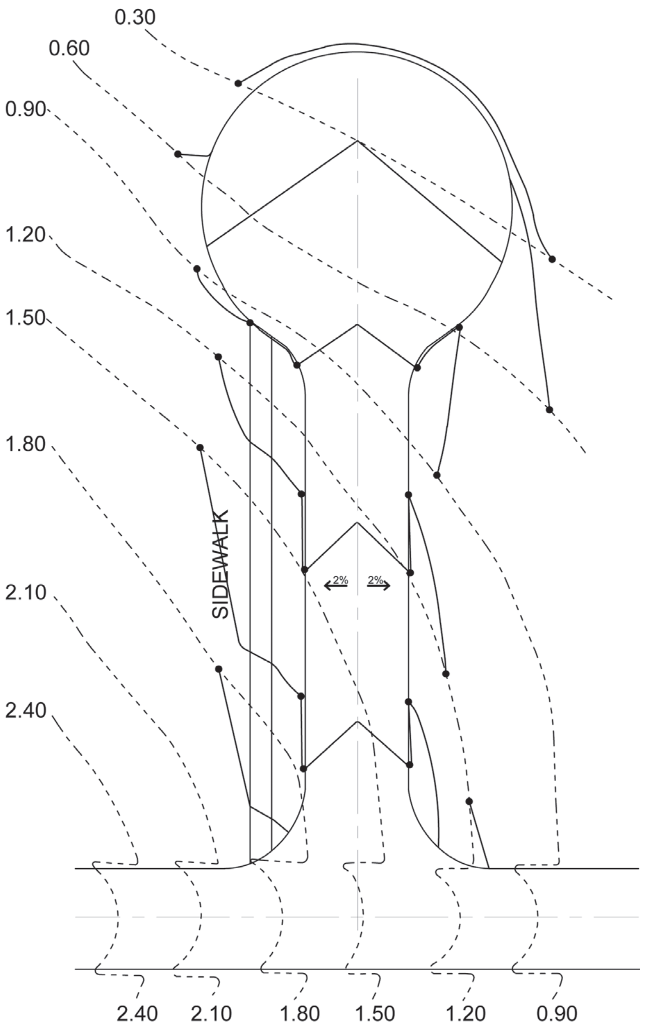
The contour lines of 1.20 meters, 0.90 meters, and 0.60 meters intersect the mid-point of the road every 14.02 meters.

3. The crown slope where the contour line of 1.20 meters intersects item 2 with the width of the road at 7.00 meters can be divided into two parts, each of which is 3.50 meters wide. The crown slope is 2%. Find the peak of the slope at 1.20 meters.

$$D = GL$$
$$= 0.02 \times 3.50$$
$$= 0.07$$

The contour line of the crown slope = 1.20 – 0.07

= 1.13 meters



4. The slope of the lengthwise road is 2.14%. The edge of the walkway is 0.15 meters Find the point where the contour line of 1.20 meters intersects.

4.1 Find the contour line of 1.20 meters at the crown slope of the road

$$D = GL$$

$$1.20 - 1.13 \text{ (from item 3)} = 0.0214 \times L$$

$$L = 0.07/0.0214$$

$$= 3.27$$

The contour line of 1.20 meters from the edge meeting the walkway on the crown slope is the contour line of more than 3.20 meters. (the contour line of 1.50 meters.)

4.2 At this same point, the height of the walkway edge is 0.15 meter Find the real point of the contour line of 1.20 meters.

$$D = GL$$

$$0.15 = 0.0214 \times L$$

$$L = 0.15/0.0214$$

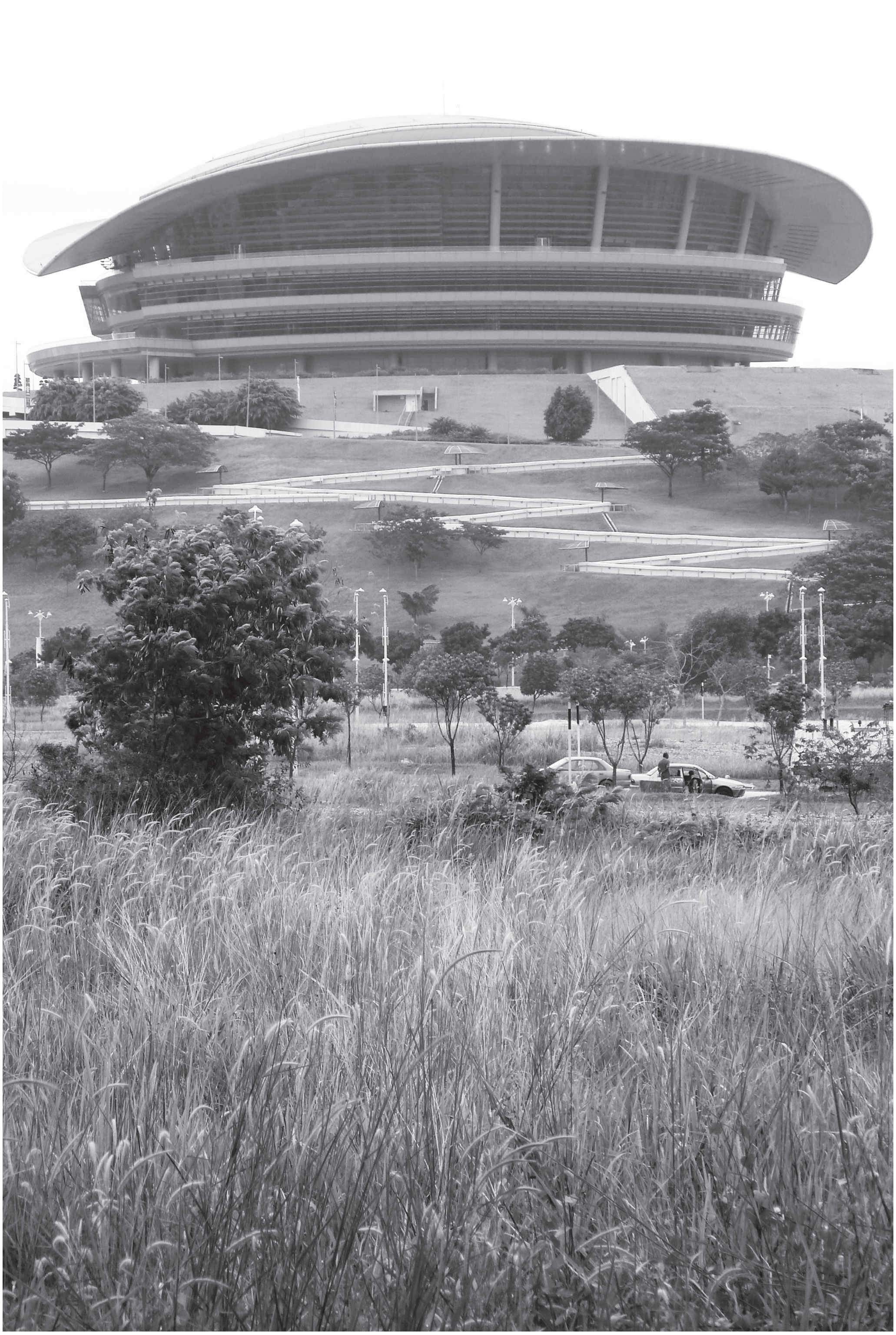
$$= 7.01$$

The contour line of 1.20 meters will run along the lower contour line for 7.01 meters (the contour line of 0.90 meters).

5. To find the contour line of 1.20 meters based on the 2% cross slope for drainage, measure the width of the grass line from the plan.

6. To find the contour line of 1.20 meters based on the 1% walkway slope for drainage and the width of the walkway is 2.00 meters.

The calculation for items 5 and 6 is like the calculation of the crown slope of the road as in items 3 and 4.1. Then adjust the contours in the Figure.



The laying of a parallel subdrain to solve the problems of high underground water level and slow drainage of multi-functional lawn in front of the Memorial of the Two Kings at Chulalongkorn University. The Figure shows the stripping of topsoil to put porous pipes in the ground and cover them with gravel and sand before growing grass on top.

Chapter 4

Drainage

4.1 Preface

More than three quarters of the earth surface is covered with water and it is the source of living organisms and of moisture in the atmosphere, creating a suitable ecology in which living organisms thrive. The surface of the earth is 75% water; in addition, water can be found in the form of vapor in the atmosphere and underground. Drainage plays an important role in landscape architecture. As explained earlier in Chapter 2 and 3 about contour lines and grading, Chapter 4 will use the knowledge and understanding of contour lines to help in drainage designs.

The concepts and objectives of drainage have changed with time. Three decades ago, drainage was to take water out of the site. Engineers had to find ways to take water out of the site as fast as possible and this had to be cost-effective. However, at present, drainage aims to retain water without causing problems to the site or its neighboring areas. The purpose is to keep the environment intact and sustainable. Engineers who deal with drainage have to work closely with landscape architects to decide where a detention area should be, how much water that area can retain, how long it can detain the storm water and which direction the runoff should be. They also have to decide what the function of that area is during the dry season and wet season.

4.2 Water cycle

Before proceeding to the techniques and the designs of drainage system, we have to understand water cycle or hydrologic cycle. The cycle starts from precipitation to infiltration, runoff, evaporation, transpiration, evapotranspiration, subsurface water or groundwater flow, aquifers ground water and stream flow. Due to global warming or climate change, the cycle has become unpredictable, resulting in severe floods or severe drought in places where it is not supposed to take place. There are more impervious surfaces because of urbanization. Trees in cities are diminished; as a result, water cannot seep into the ground leading to the reduction of the underground water level.

4.3 Water management concept

Suitable water management is essential to ensure enough water for consumption with minimum initial cost so that engineering and landscape architecture elements can be designed. Provision of reasonable amounts of water throughout the year is also important for industries, irrigation, parks, households, hotels, golf courses and agriculture.

Figure 4.2 A watershed is a ridge of land dividing two adjacent rivers or lakes with respect to the flow of water by natural channels into them such as the catch basin above the dam, weir or reservoir.The water in basin no.

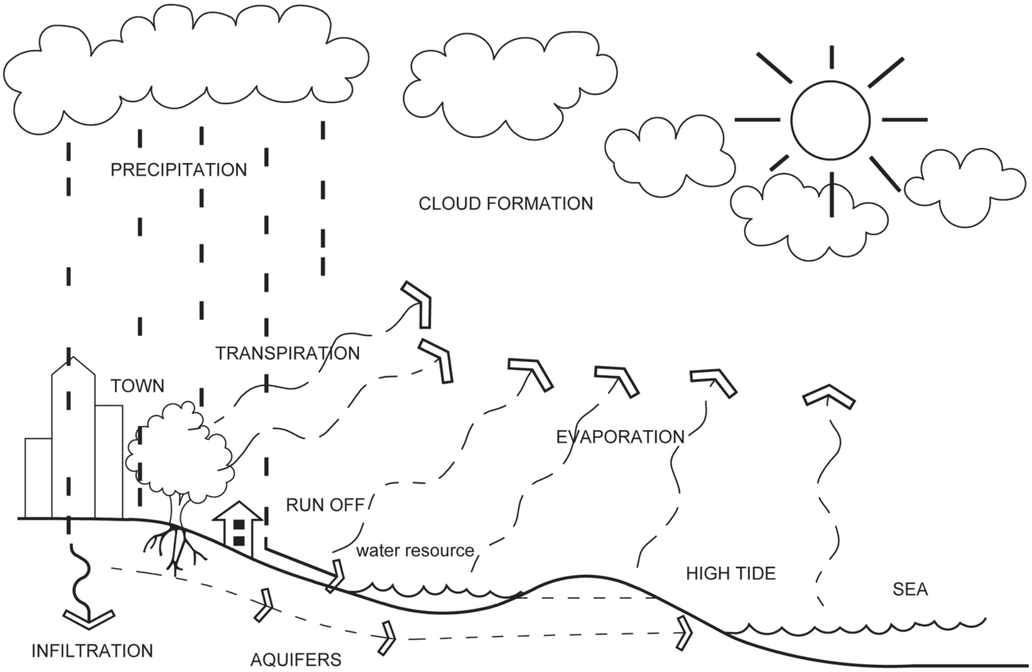


Figure 4.1 *The water cycle*

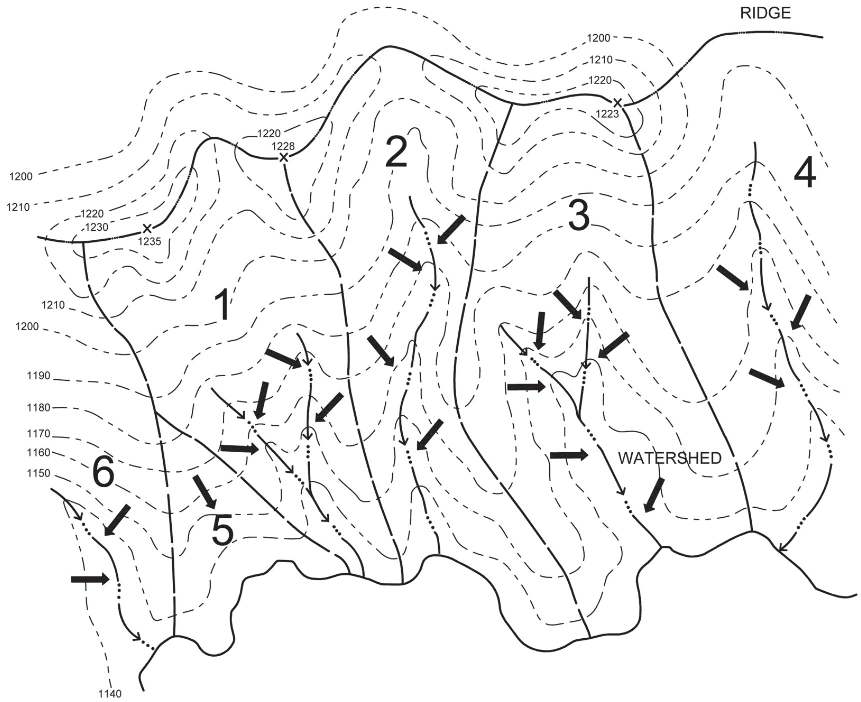


Figure 4.2 *The watershed lines divide water catchment area*

1-6 will be conveyed into the same catchment or reservoir. It is like a roof directing rainwater into the water jar. Architects and engineers have to estimate the amount of runoff from the watershed to the other areas and decide which approach is appropriate for conveying this water into the outlet.

When it rains, the water can be termed as follows:

1. Surface runoff. Some water will flow into rivers or canals and eventually into the sea. If water is to be kept, it is easily done by directing water flow into reservoirs, retention ponds or detention areas.

2. Underground drainage. Some water will seep into the underground level, but the flowing rate is different depending on the types of soil. (see Figure 4.3)

3. Evaporation. The evaporation rate depends on the relative humidity in each region. The more the surface is exposed to the sun, the higher the evaporation rate.

4. Transpiration. The roots of plants will take some water for photosynthesis. Figure 4.3 illustrates the relationship between land use and the perviousness of water. Because of urbanization, some agricultural areas have turned into houses and roads; therefore, there is more impervious surface. Urban developers have to consider the effects of the development on natural pervious surface.

4.4 The main objective of drainage

Initially, the main objective of drainage was to prevent the site from being flooded but the runoff is conveyed into public sewers or neighboring areas and this can cause problems to those areas. The principle of drainage focuses on collection, disposal and conduction of water but today this has changed into designing system to retain water, draining water and efficient management of water. The object of drainage changes as time passes. In the past, the object is

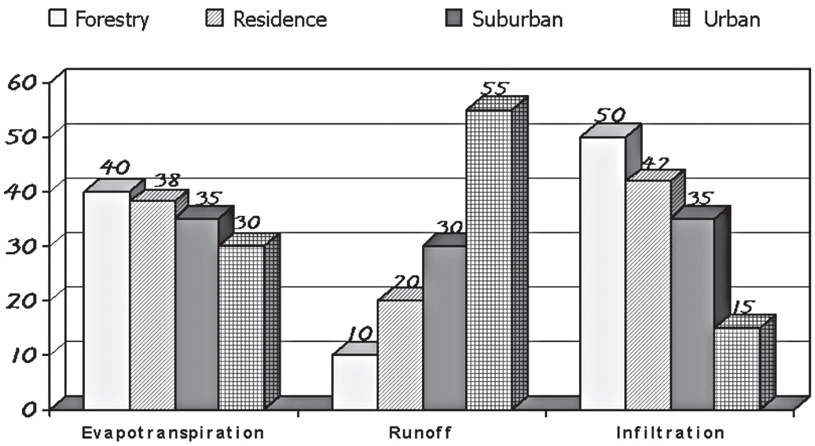


Figure 4.3 *Chart showing the relationship between the use of land and the absorption of rainfall*

to drain water out of the area as fast as possible using storm drainage channels, swales, gutters and to drain water to the nearest public waterways in order to.

1. prevent soil erosion by slowing the flow and the amount of runoff.
2. reduce problems caused by floods and enhance the land use.
3. promote the growth of plants by draining excessive water from saturated soil.
4. reduce water in the soil so it can bear more weight and be used for other purposes.

Present, off-site impacts are taken into consideration to reduce downstream flooding by applying detention facilities to reduce runoff and damage caused by floods. Flood plain development, therefore, is important to control the flow of runoff.

In the future, ideas about the amount and quality of water in urban areas will be integrated with ideas about the amount, collection, detention, storage and infiltration. Approaches of rain harvesting, erosion prevention and control of silt sedimentation should be applied to reduce cost.

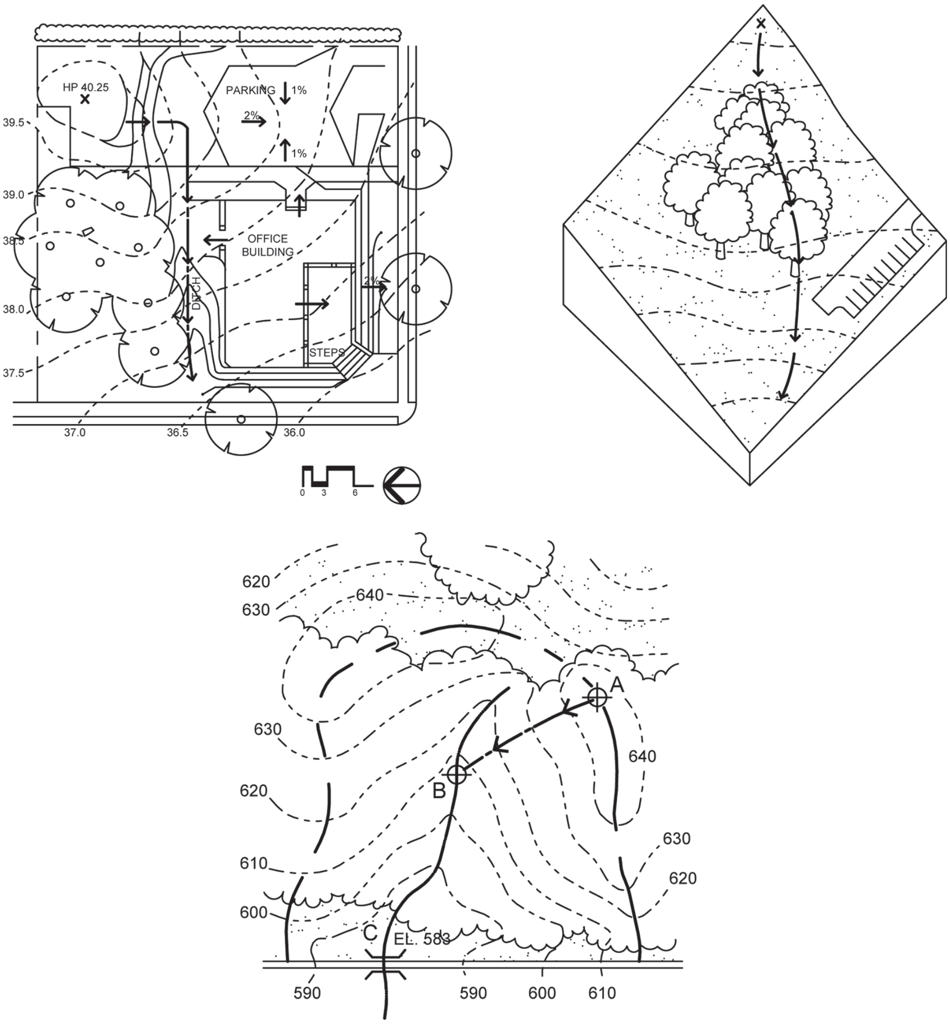


Figure 4.4 *Drainage at different levels. (From left to right: site level, neighboring level, and basin level.)*

4.5 Rain drainage system

As mentioned earlier, rainwater can be divided into two portions; first portion seeps into ground to be aquifers/sub-surface/ground water and another portion flows as natural surface runoff or unnatural surfaces such as roofs or roads. Water management in urban areas has to start from the site to the vicinity as follows:

Site level – floods, retention, erosion

Federal, state, local level – according to the laws about discharge/recharge of water to water sources and the surrounding areas

Regional level – erosion/sedimentation, pollution caused by accumulation of wastes carried by runoff

Climate specific level – underground water, soil subsidence, land slide floods, drought

Rain water management can be categorized into four approaches:

1. Watershed-based storm water management. This focuses on cost-effectiveness, environment, and systematic planning about management and policy.
2. Reduction in imperviousness. This focuses on the least disturbance of nature, reduction in pavement or use of materials that are permeable.
3. Best management practices (BMPs), integration of storm water management, water quality and site conditions in terms of climate, soil, landform, land use and pavement.
4. Retention/dry pond, detention/infiltration basin

At first we have to understand the principles of drainage in the past since they combined grading with drainage. An understanding of the principles of drainage will lead to the conveyance of water into a desired place and then to retain, detain and discharge water efficiently.

4.6 Factors determining the drainage system

Factors that determine the drainage system are:

1. **Land use**. Impervious surface resulting from urban development affects the runoff. The perviousness of areas covered with vegetation are different from those of residential and commercial areas. Unlike rural areas, the land

where houses or factories are located is covered with pavement, roofs, roads and the built-up areas slow the runoff so more water accumulates on the surface, causing disasters such as landslides and severe floods when the flood plains are trespassed or agricultural areas on the terrace where seedlings or annual crops are planted but cannot hold the soil.

2. **Landform**. Geographical conditions – plains, slopes or hills – affect the flow and speed of water. The slope makes the water flow faster and erodes more topsoil. To deal with this, the drainage channels have to be wide and strong. The plain and the valley tend to become flooded easily. The design of the drainage system has to blend in with the landform and land use.

3. **Size of drainage area**. This refers to the area that collects rainwater – the lawn, road surface, ground, walkway and building – the wider the area, the more water it can collect. Even though the basin and the valley are small in area, the estimate of a catchment basin has to take into account areas up to watershed line that forces water to flow through the site.

4. **Types of soil**. The infiltration of fine and compact soil is lower than sand because sand is porous. The rate of erosion also depends on the quality of soil and to prevent erosion, ground cover has to be grown to hold the soil. The silt sedimentation can cause congestion in the drainage channels.

5. **Ground cover** such as grass that is cut short in a sports field and grass in the natural environment has different effects on drainage. Different types of ground cover can hold water and retain it differently.

6. **The amount and frequency of rain**. Landscape architects have to study the amount of rain so as to determine the volume of water at a certain time so they can design an appropriate drainage system.

4.7 Good practices for drainage

Decha Boonkham (1979) wrote a book in Thai about site planning and site work and he mentioned the following good practices for drainage:

1. The gravity is the force that causes water to flow downwards; therefore, a right slope plays an important role in drainage.
2. Water always flows at the right angle against the contour line.
3. Delaying the flow of runoff has a positive effect on ecology because more water can permeate into the soil.
4. The water from the drainage system should not flow in others' areas except in existing natural waterways.
5. The major problem in drainage is erosion; as a result, designing a suitable slope to prevent erosion is necessary. Ground cover should be planted immediately after grading.
6. Slow-flowing water results in puddles or marsh land but fast-flowing water results in gullies.
7. Surface drainage is better than letting water flow through underground pipes because clogging can occur in the pipes, a pipe network is more expensive and water cannot permeate into the soil.
8. Man-made drainage should work like a natural one.
9. A hard pavement with a steep slope does not look good so, if possible, the slope of a hard pavement should not be too steep.
10. A large amount of water from a parking lot or other open space should be kept in a sump before flowing to the walkway or to the road.
11. A backup plan for drainage should be available in case that the existing drainage outlet is clogged.

Figure 4.5 *The storm drainage system at Asian Institute of Technology is separated from the sewer system. The drainage system is big enough to accommodate a large amount of water. The Figure shows different kinds of drainage system, catch basins and detention areas in the institute.*

LAND USE	C
1. ROAD	
PAVEMENT, CONCRETE ROAD	0.70 - 0.95
BRICK ROAD, CONCRETE SLAB	0.70 - 0.85
2. ROOF	0.75 - 0.95
3. LAWN (SILTY SAND)	
WITH 2% SLOPE	0.05 - 0.10
WITH 2% TO 7% SLOPE	0.10 - 0.15
7% STEEP SLOPE	0.15 - 0.20
3. LAWN (CLAY)	
WITH 2% SLOPE	0.13 - 0.17
WITH 2% TO 7% SLOPE	0.18 - 0.22
7% STEEP SLOPE	0.25 - 0.35

LAND USE	C
COMMERCIAL ZONE	
COMMERCIAL USES	0.70 - 0.95
RETAILS AND COMMERCIAL USES	0.50 - 0.70
RESIDENTIAL ZONE	
SINGLE HOUSING	0.30 - 0.50
TWIN HOUSING	0.40 - 0.60
TOWNHOUSE	0.60 - 0.75
SUBURBAN HOUSING	0.25 - 0.40
APARTMENT AND BUILDING	0.50 - 0.70
INDUSTRIAL ZONE	
LIGHT INDUSTRY	0.50 - 0.80
HEAVY INDUSTRY	0.60 - 0.90
PUBLIC PARK	0.10 - 0.25
SPORT AND KID'S PLAY	0.20 - 0.35
TRANSPORTATION	0.20 - 0.35
BLANK SPACE	0.10 - 0.30

Figure 4.6 *Table showing runoff coefficients based on the use of land (left) and the types of surface (right) produced by The American Society of Civil Engineers (ASCE).*

4.8 Storm drain from flooded areas

A lot of rainwater coupled with floods or high tide poses a difficulty in developing an area. The site drainage including rainwater and waste water has to be in line with other facilities in the project and follow the rules and regulations. In addition to a proper drainage system, its maintenance is another issue to be considered. If the project covers a large area and some of it is being developed while the other will be further developed, a master plan or a phasing plan has to be mapped out.

A change in the land use of the site will affect the adjacent areas at a certain level. For example, an industrial estate project will affect the use of water and the impervious surface. The rainwater that used to permeate into the ground at the site will run onto another area and can cause flooding in areas that was never flooded. Another case in point is the construction of a large dam or a reservoir that affects the ecology and the water levels above and below the dam or the reservoir.

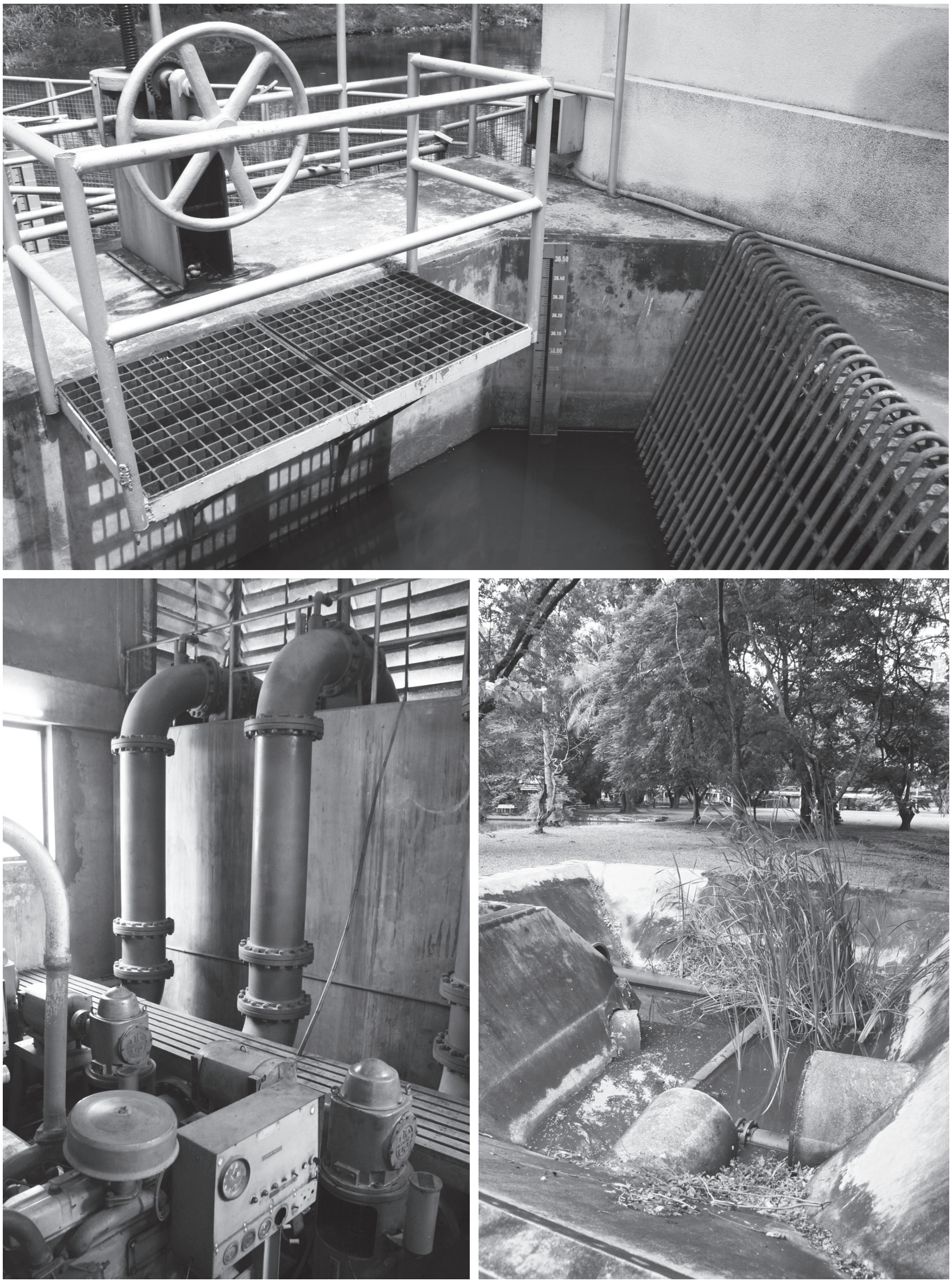
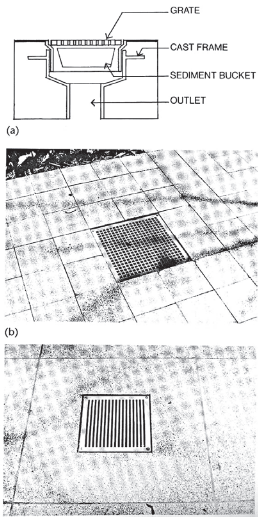
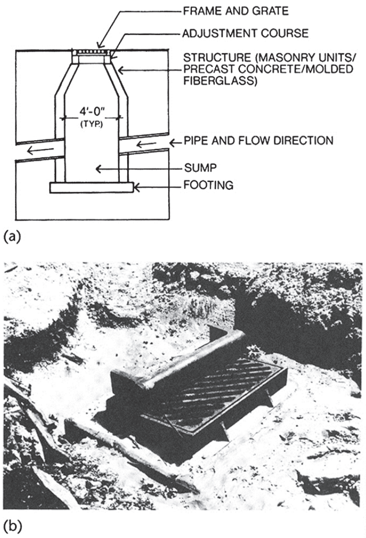


Figure 4.7 The pump building with storm sewer out falls at the Asian Institute of Technology.

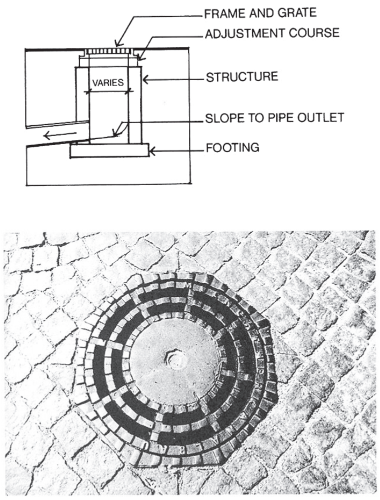
Figure 4.8 *The open drainage system in the slope landform. The slope surface should be paved to prevent erosion.*



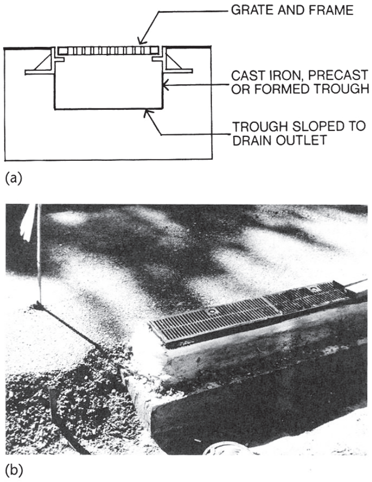
area drain



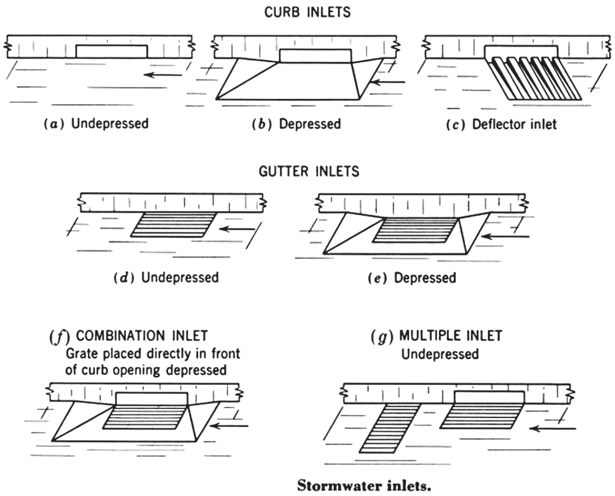
sump/catch basin



drain inlet



trench drain



drain inlet along the road

Figure 4.9 *Examples of drainage systems (Sumet Sangalangkarn, 2005)*

4.9 Elements of a drainage system

Designing the drainage system involves managing the elements of the drainage system and includes the following:

1. **Manhole**. This can be round or square with a lid but round is better than square because the lid will not easily fall through the hole. They are usually located every 8 meters.

2. **Storm-water drain inlets** that are usually located at the low point (LP) of the area, along the roadside or walkway. These are rather small and conduct water to the pipes. There are no catch basins at this point.

3. **Area drains** that can be found in a large area where manholes are not enough to drain a large amount of water immediately. Usually found on a pavement with the area of 90-180 square meters, in a form of a mesh that can filter out rubbish and prevent a vehicle or a person from tripping and falling into the hole.

4. **Trench drain/French drain**. That receives sheet flows water. This is found lengthwise on the concrete surface. There are three types: the edge of a parking lot, a trough around the structure and a trough with gravel.

5. **Catch basin**. In general, this is a pre-cast concrete pipe with the diameter of 800-1200 mm. One catch basin is located in a catchment area of about 930 square meters.

6. **Pipes/conduits** that convey water from one place to another with the help of gravity. They are made of various materials such as ceramics (used in other countries, acid resistant but fragile), ferro-concrete (not acid resistant), reinforced concrete (long but not acid resistant), PVC (sturdy, light and acid resistant), ductile iron (cannot resist salty soil), asbestos cement or fiber cement (not popular, fragile and not acid resistant).

7. **Detention/retention basin**. This can be a marsh or a dry area that can detain a large amount of water.

8. **Sediment/infiltration basin**. It is a dry basin that collects water and let it seep to the soil.

9. **Storm sewer outfalls**. The water is released to the public sewers and the outfalls can be equipped with a pumping tower or a wire mesh to catch rubbish. (Figure 4.7)

10. **Overflow run-off channel, spillway**. This is used to control the level of water.

11. **Open channels**. They replace pipes, bear a lot of weight and are easy to maintain.

12. **Splash blocks**. They are installed at the lowest part of the trough to reduce erosion.

13. **Soakaway & catch pit**. The gravels buffer the splash.

14. **Sump** that is usually near the pumping station, use for holding water until the volume is enough to pump.

15. **A culvert** that can be either a round concrete culvert or a box concrete culvert. This is usually under the road, railroad or waterway.

16. **A chute** that is used to convey water from the high ground to the lower ground.

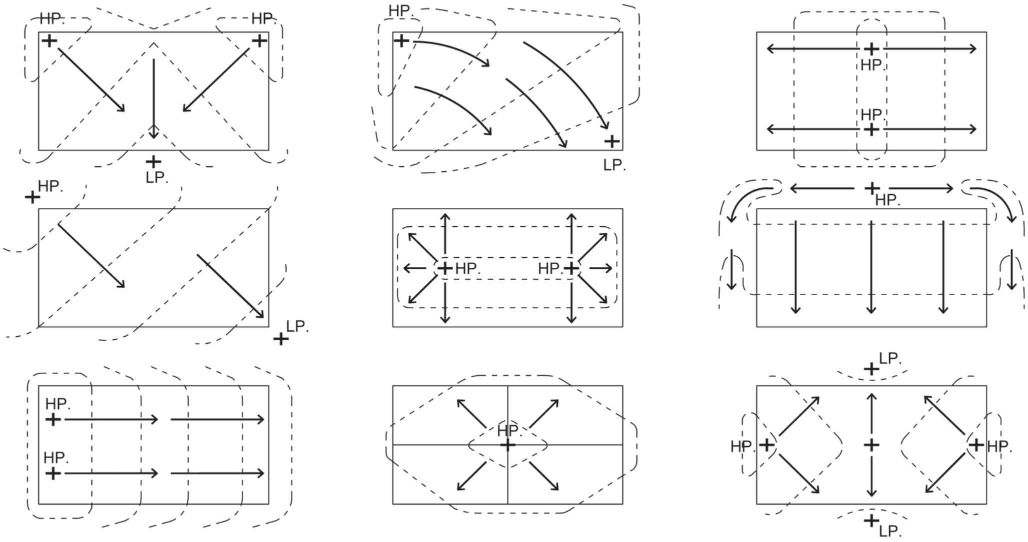


Figure 4.10 *Patterns of drainage on the plain*

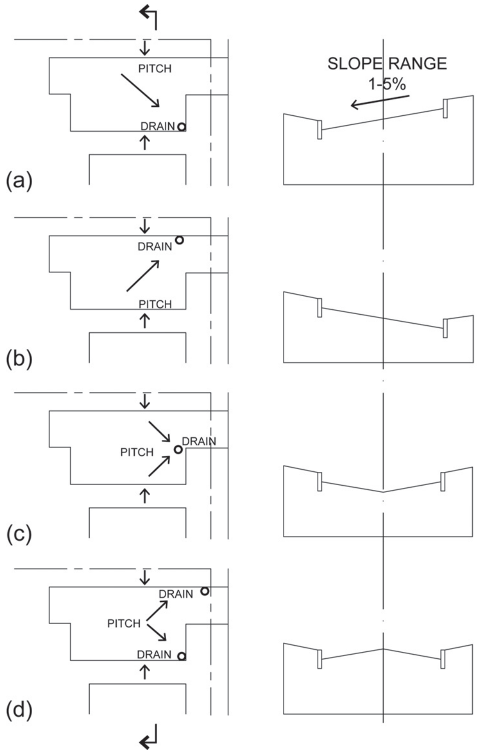


Figure 4.11 *Plans and cross sections of drainage in the parking lot*

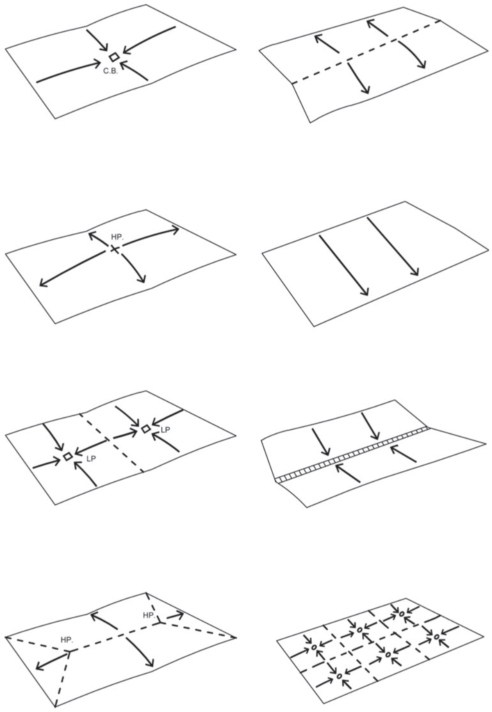


Figure 4.12 *Directions of water flow on different surfaces*

4.10 Drainage process

The first step for draining water is to analyze the characteristics of the land to find existing drainage pattern, followed by evaluating the area where water is going to be emptied, choosing an appropriate pattern of drainage, locating inlets, specifying the elevation of the edge, locating directions of channels, studying the cross section of drainage and going into details about the elevations/ sizes of drainage structure.

The drainage system can be divided into the open system, the closed system and the combined system. The advantages of the closed system are that it covers a small area but is difficult to maintain and more expensive than the open system. The drainage system can be also divided into five major systems.

1. A surface drainage system that can be further divided into a sloping plane, sloping plane with valley, and funnel system. The pattern and direction can vary (Figure 4.10, 4.12). The water is drained through swales, which is easy to maintain and cheaper than the underground system. The surface drainage system can be equipped with or without a wire mesh with a sump or with grass covering it.

2. An enclosed underground drainage system. It is a way to collect water and convey it to the public sewers. This system requires an area drain, catch basins and trench drain/French drain.

3. An enclosed underground drainage system with on-site storage. This is similar to the second system but it is used in a project that has an enough area to hold a lot of water before letting it seep into the ground or releasing it outside the site when the water overflows the storage area.

4. A combination system with enclosed drainage for paved areas and surface drainage for unpaved areas. The paved areas can be parking lots, sports grounds such as basketball courts or tennis courts while an example of an unpaved area is a lawn.

5. Drainage on saddles is usually made into steps to delay and direct the flow of water so that it cannot damage the site. This system requires an interceptor ditch and terrace. Ground cover including a wire mesh or a sheet can be used to prevent soil erosion. Paving the ditch or terrace can also prevent soil erosion.

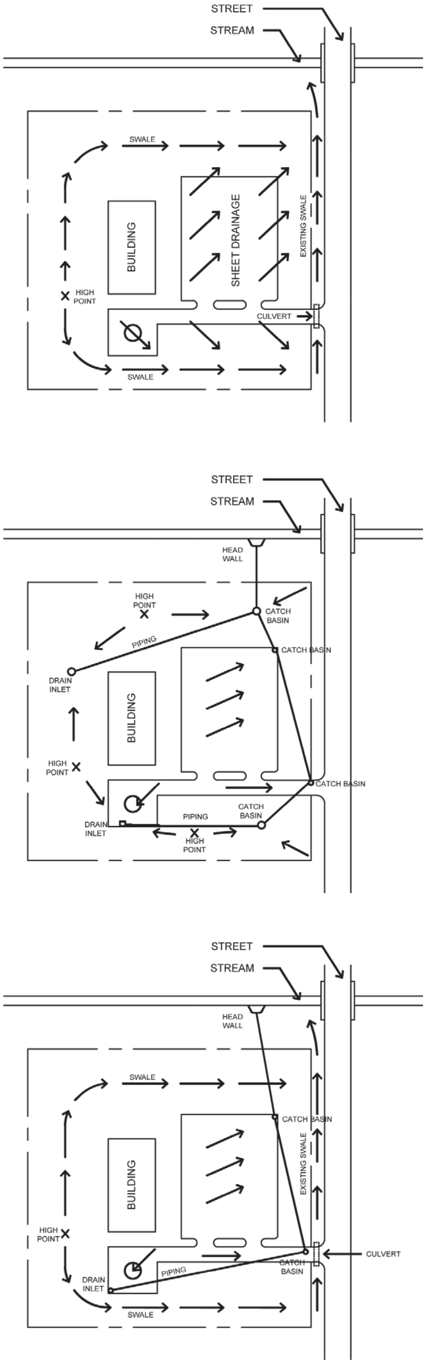


Figure 4.13 *Surface drainage system (above), closed system (middle) and a combined systems (below)*

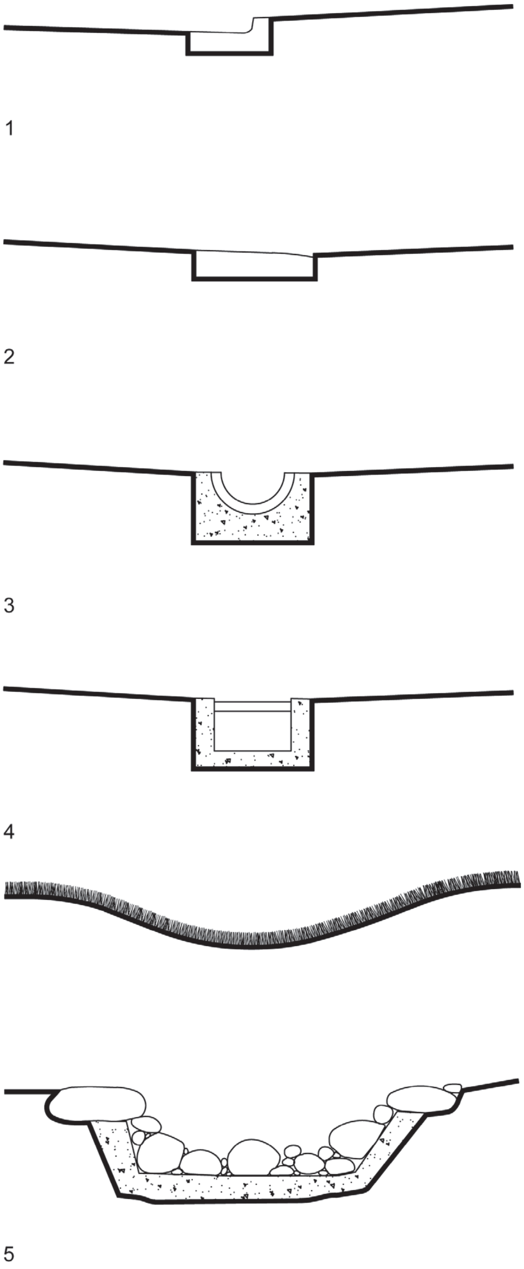


Figure 4.14 *Gutters and open channels in the open drainage system*

Figure 4.15 *The construction of the new closed drainage system in chulalongkorn University. The old road surface was stripped to make way for the drainage system and other public utilities. Then they were covered, graded and paved with concrete.*

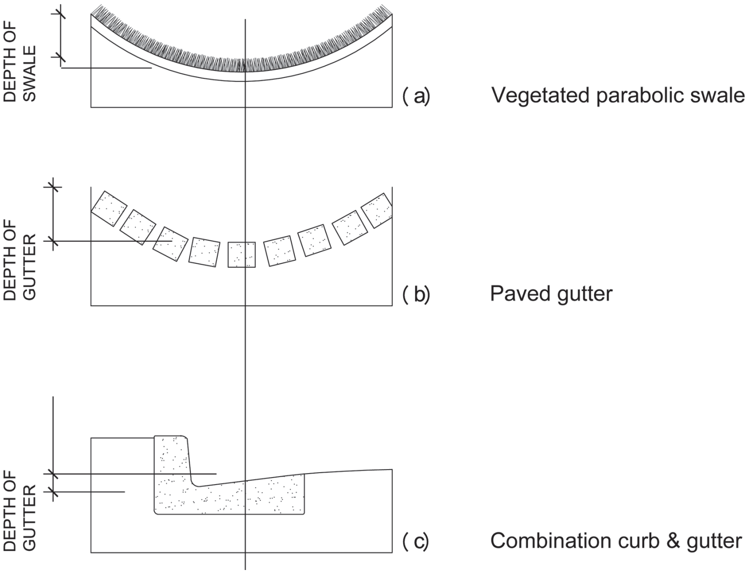


Figure 4.16 Drainage channels in the open drainage system

Pervious Concrete

Source: *The Concrete Promotional Group of Greater Kansas City*

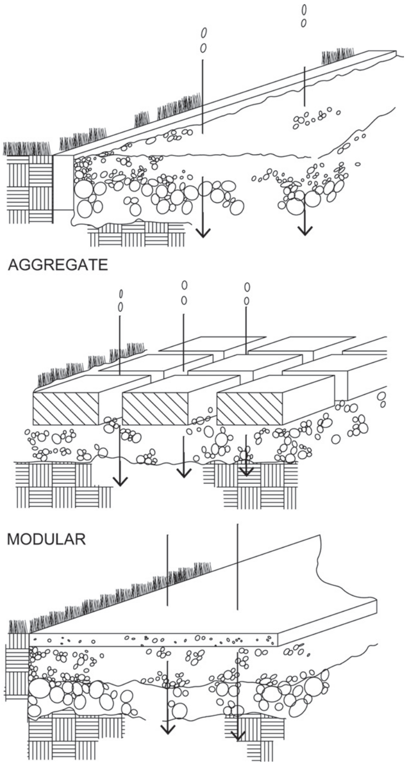


Figure 4.17 Pervious surfaces such as pervious concrete/porous concrete, porous block

4.11 Principles of drainage system design

The principles involve suitable grading and drainage. The water has to be drained from various types of surface and the cross section of the drainage has to be wide enough to drain the water out of the site and be safe for people and vehicles. The cost and maintenance as well as adherence to the law are also important issues. A good drainage system should be easy to maintain, for example, it can get rid of silt or dirt by itself. To design the drainage system, landscape architects have to calculate carrying capacity, cross section, flow rate, slope of trough and material use for pavement or ground cover. Designing the drainage system is based on statistics so it is a rough calculation using statistic dates or amount of water, rainfall and coefficient. Related formulas used in designing the drainage system are:

1. G = D/L
2. Q = CiA (Rational Method)
3. Manning's formula by using a monograph to determine the Tc (Time of Concentration) and flow time used in calculating draining pipes
4. Charts, Rainfall Intensity Curve (IDF-Curve), statistics about amount of rainfall
5. Tables showing C (Runoff Coefficients), coefficients of friction of material n, return period, cross section of pipes and hydraulic radius, wetted perimeter
6. Advanced method I = Intensity, D = Duration, F = Frequency (Bangkok = $I_5 = 6994/(Tc + 34)^{0.99}$)

The related factors are

rainfall – amount and duration of rainfall

watershed – area to collect water

drainage/catchment point – pattern of drainage and location and number of catchment points

infiltration – use of land and materials to pave the area

aquifer – level of underground water

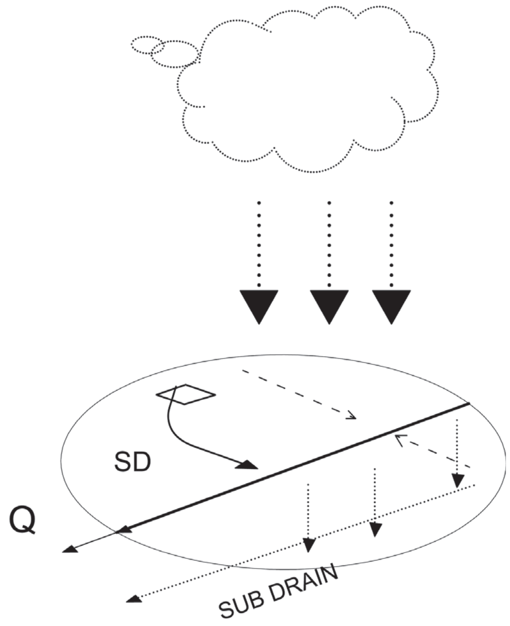


Figure 4.18 *Calculation of drainage system*

The frequency and duration of rainfall depend on the geographical conditions of the site.

Type of area	**Frequency/Time**
<u>Storm sewers</u>	
City, village with 5000 residents	2-5 years/hour
5000-10000 residents	5 years/hour
10000 + residents	10 years/hour

Culverts	
Intersection	25 years/24 hours
Entrance	10 years/24 hours
Roadside ditches	
Main road	25 years/24 hours
Secondary road/local road	10 years/24 hours
Pond spillways	
Main pond	25/50 years/24 hours
Temporary pond	100 years/24 hours

*The flow rate of rainfall (Q) is calculated in cubic meters per second

Steps of calculation

Step 1: Calculating surface water flow rate based on the following formula Rational Formula: $Q = 0.278 \times 10^{-6}\ CiA$ This formula is suitable for a catchment area of not more than 2.5 square kilometers. (as for a bigger area, other formulas such as hydrograph should be used).

Q = flow rate, cubic meter/second

C = runoff coefficients (Consult Table for C) depending on the use of land

i = intensity of rainfall, millimeter/hour (Consult IDF Curve)

A = rainfall catchment area, square meter

Runoff coefficients (C)

Type of area		Runoff coefficients (C)
Dense business zone		0.70-0.95
Around business zone		0.50-0.70
Residential zone	: single family	0.30-0.50
	: many families separated	0.40-0.60
	: many families near each other	0.60-0.75
	: suburbs	0.25-0.40

Type of area	Runoff coefficients (C)
Apartment zone	0.50-0.70
Light industrial zone	0.50-0.80
Heavy industrial zone	0.60-0.90
Public park	0.10-0.25
Playground	0.20-0.35
Train station, junction	0.20-0.35
Abandoned area	0.10-0.30
Concrete surface or asphalt surface	0.70-0.95
Brick surface	0.70-0.85
Roof	0.75-0.95
Sandy soil plot: plain – 2% slope	0.05-0.10
Sandy soil plot: 2-7% slope	0.10-0.15
Sandy soil plot: greater than 7% slope	0.15-0.20
Compact soil plot: plain – 2% slope	0.13-0.17
Compact soil plot: 2-7% slope	0.18-0.22
Compact soil plot: greater than 7% slope	0.25-0.35

In this step, the calculation is based on the IDF-Curveor the graph showing rainfall intensity (I), duration (D) and return of period in year, which are the meteorological statistics of each region.

After that, frequency or return period is applied based on the size of the project and its capital investment. In general, a big project such as an airport or a dam cannot risk flooding so its frequency is at 100 years and a small project can be from 15-50 years.

Residential area	5-15 years
Commercial area	10-15 years
Important area, expensive and severe damage	10-50 years
Flood prevention work	more than 50 years

Agricultural area drainage	5-50 years
Rain trough in small city	5-25 years
Rain trough in big city	25-50 years
Airport	more than 100 years
Dam preventing floods	50-200 years

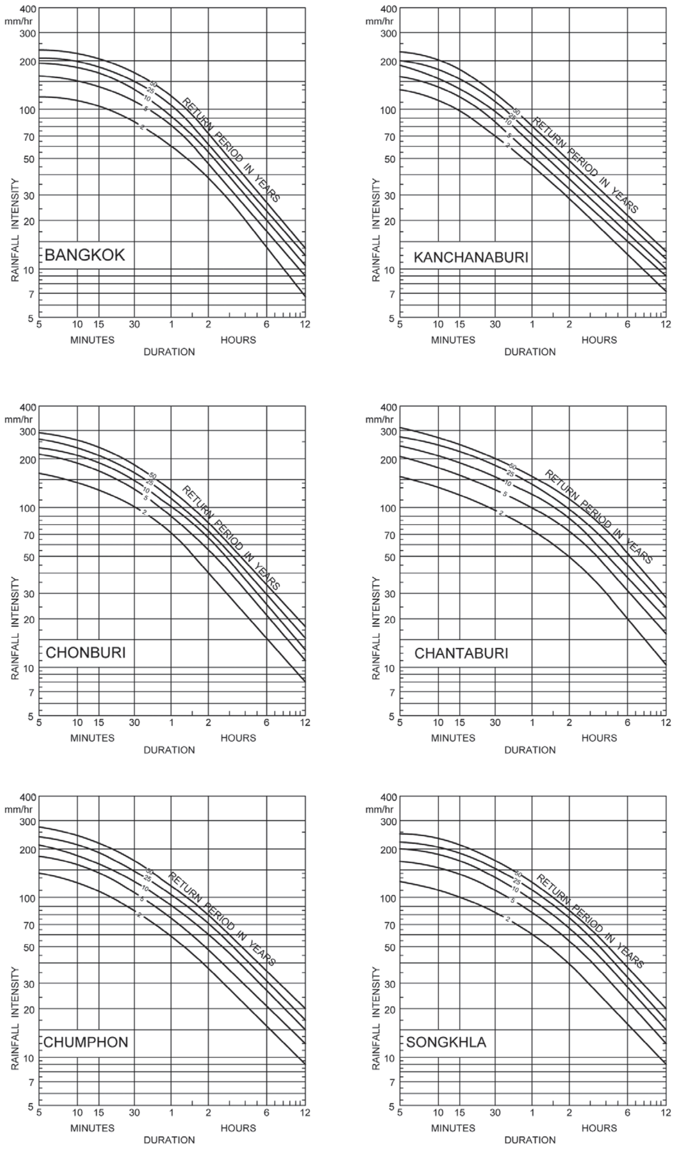
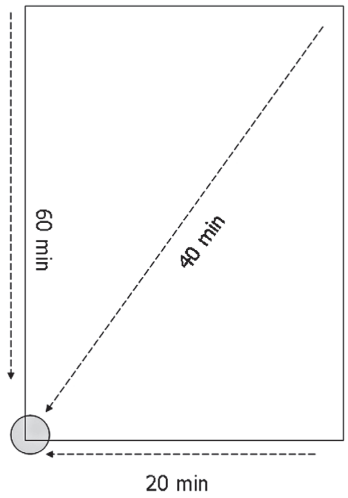


Figure 4.19 *Examples of IDF-Curve in 6 provinces in Thailand (Mustonen, 1969)*



Time of concentration (Tc) refers to the time when rainfall flows from the farthest area to the ditch and to the place being considered. The highest rate of runoff may not take place at the time of concentration. Tc is calculated by using the formula FAA

Tc = 0.702 (1.1 – C) L 0.5S – 0.333

(If L = < 250 m.)

Or Tc = 0.994 (1.1 – C) L 0.5S – 0.333

(If L = > 250 m.)

Tc = Time of Concentration (minute)

L = Length of overland flow (meter)

S = Surface slope (m./m.)

C = Runoff coefficients

This formula is used with an overland flow graph or the following options

As for a hard surface, crowded structures, with lot of manholes such as in a city, Tc is 5-10 minutes.

As for most developed areas with relatively flat surfaces, Tc is 10-15 minutes.

As for residential communities on flat terrain, Tc is 20-30 minutes.

As for a concrete area, Tc is about 15 minutes; however, it should not be less than 15 minutes because it is a waste for A. The A should be set aside for the future and the C has to follow the A to save the costs of construction.

The return period follows the expensive area of the project while the return period 50-100 years of a cheaper area is calculated at 15 years. The cost of 10 years rainfall is more expensive that of 5-year rainfall by 5-10% (as a result, the size of the pipe can be bigger to cover the larger amount of rainfall). Tc is usually 15 minutes. As for residential areas, it is 20-30 minutes. For an area that runs a risk of floods, Tc is lower while the Q and the return period are high.

Step 2: Designing pipe and manhole. The calculation of pipe is based on Manning's formula

$v = (1/n)R^{0.67}S^{0.5}$

$v = (0.397/n)D^{0.67}S^{0.5}$

$Q = Av$

v = flow velocity (m./second)

n = Manning's friction coefficient

A = cross section area of flow (sq.m.)

R = hydraulic radius (m.)

$= \frac{A \text{ (sq.m.)}}{\text{wetted perimeter (m.)}}$

S = slope of pipe or water surface (m./m.)

D = diameter of round pipe used when the pipe is full (m.)

Q = rate of flow (cubic meter/second)

The calculation of curb gutter & inlets can be divided into:

1. The calculation of curb gutter based on monograph
2. The calculation of curb inlets based on monograph and the following formula

$Q_i = 1.269 (L + 1.8 W)d^{1.5}$ (When inlets are not flooded.)

Or $Q_i = 2.966 hL(d_0)^{0.5}$ (When inlets are flooded.)

Q_i = inlets capacity ($m.^3/s$)

L = inlets opening length (m.)

h = inlets opening height (m.)

W = lateral width of depression (m.)

d = depth of flow at curb (m.)

d_0 = effective head (m.)

3. The calculation of gutter inlets. Formula: $Q = 2.966\ Ad^{0.5}$

Q = inlets capacity ($m.^3/s$)

A = clear opening area of grate ($m.^2$)

d = flow depth (m.)

Step 3: Choosing a pipe such as ferro-concrete pipe, reinforced concrete pipe, PVC pipe, HDPE (light and flexible plastic) pipe, ceramic pipe, ductile iron pipe and fiber cement pipe.

Things to be considered when conducting field work (Sumet Sangalangkarn, 2005)

1. The deeper the pipe, the more pressure it has to bear; therefore, the depth for laying pipes is important.
2. The wider the trench, the heavier the load it has to take.
3. If the underground water covers the ditch, the water has to be pumped out or a subdrain has to be used.
4. The piping is done from the end to the top.
5. When the piping is done, all the pipes should be covered immediately.
6. Pay attention to uplift.
7. Applying pressure on the pipes should be done only by hand or light machinery.
8. To remove the pole structure to prevent soil collapse set up during the construction should be done in order and all the holes should be filled with sand or cutting it off just above the pipe line.
9. The sheet pile can be removed for future use because it is light and does not make a hole in the ground.

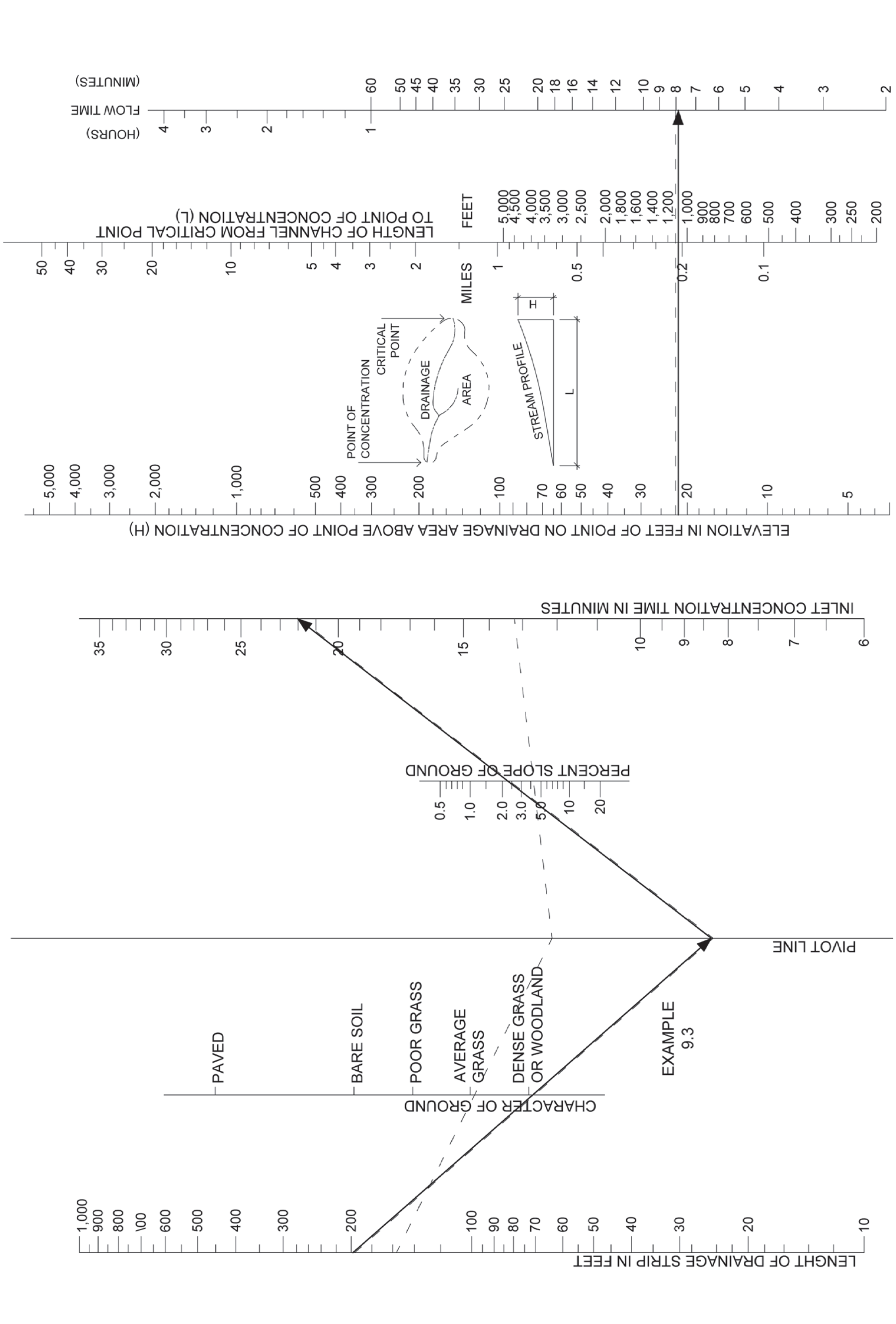


Figure 4.20 The use of monograph to find Tc, flow time

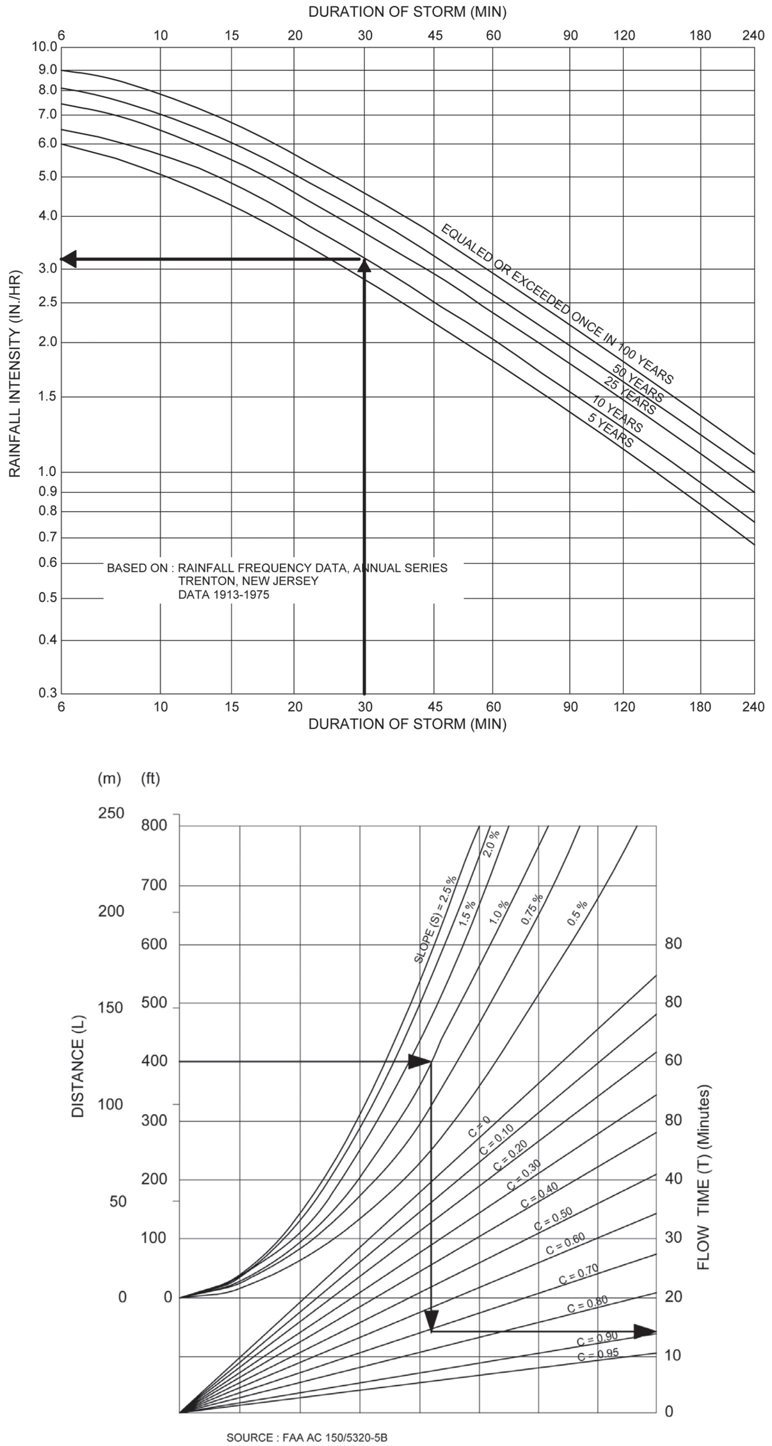


Figure 4.21 *The use of monograph to find time of concentration (above), rainfall, intensity and curves (below)*

Figure 4.22 *The drainage system in Columbus, Ohio, U.S.A. The system is environmentally friendly as seen from the sign "Dump no waste drains to river" because the water flow into the rivers. On both sides of the road, there are rain gardens to retain storm water.*

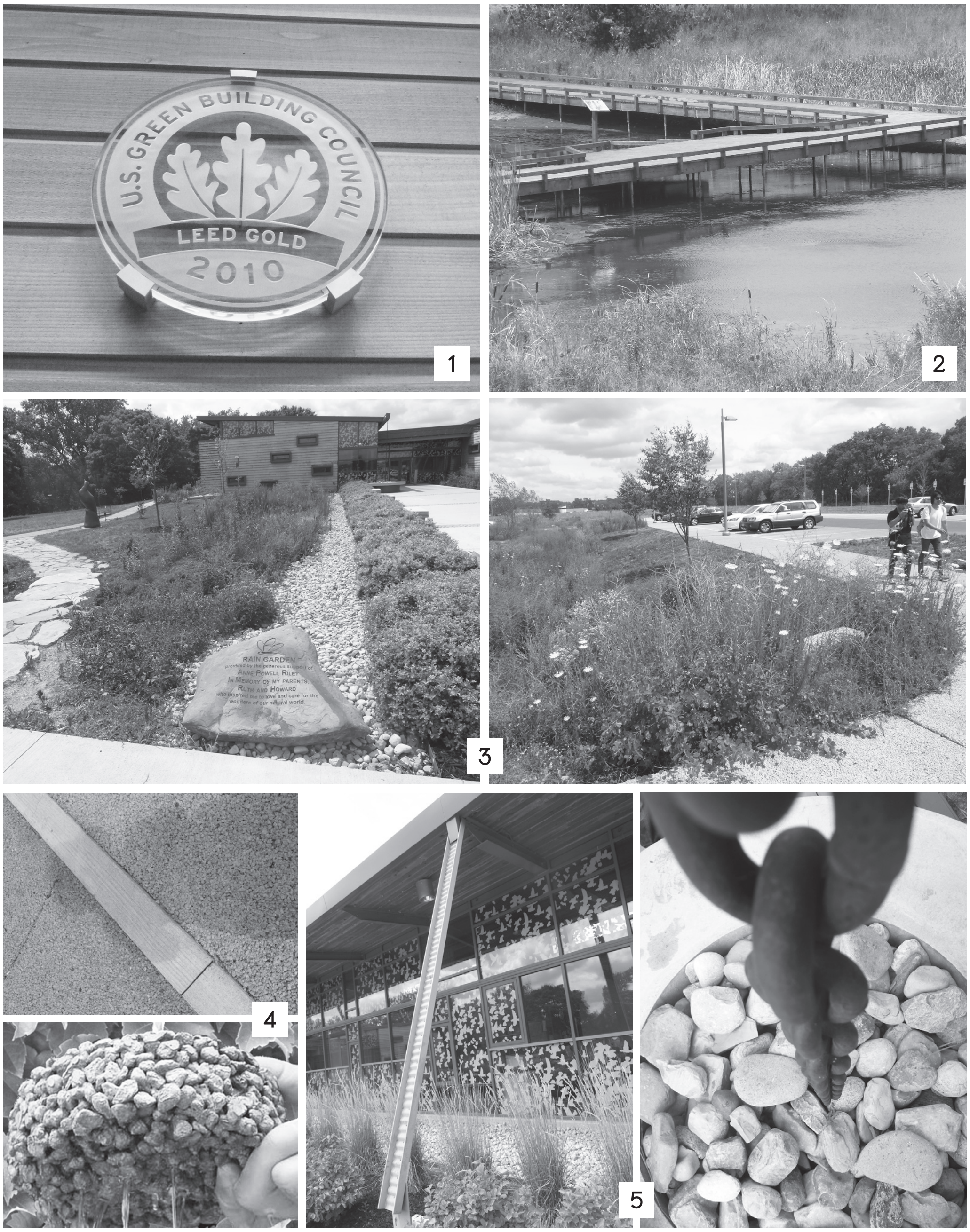


Figure 4.23 *The Grange Insurance Audubon Center in Metro Park, Columbus, Ohio, U.S.A. The concept is zero run-off and the architecture design was awarded LEEDS Gold Green Building [1] due to the application of water detention areas [2] such as a rain garden [3], porous concrete [4] and rain harvesting [5].*

4.12 Subdrain

A subdrain helps drain sub-surface/ground water from the site so that the soil will not be too wet and soggy and this can prevent the underground water level from getting too high. A subdrain is carried out in outdoor athletic courts such as football pitches, lawn tennis courts and bowling lawns. To make a suitable slope for surface drainage on such courts is difficult; as a result, water has to flow slowly on the surface and most water seeps into the ground so there is a pool of water underground or on areas around the courts that are lower than the courts. A subdrain is an appropriate approach.

A subdrain can be done by placing a perforated pipe around it or a prefabricated pipe for a subdrain (the diameters are between 15 m.-20 cm.) on a 1-3% slope ditch filled with small gravel or broken bricks at 0.75-1.50 m. below the surface ground and covering it with soil. To design a subdrain, landscape architects have to consider the directions of the pipe lines, the slope of the pipe lines and the size of the drained area as well as the size of the pipe and its spacing. In general, the distance between each pipe lines is about 7-8 meters.

The pattern of a subdrain varies depending on the landform; for example, it can follow the landform, be in harring bone form and all the water flows to the ridge in the middle, or be in a grid form. An inceptor can be placed in the lower part where more water is collected before releasing the water to another catchment area/outside the site (Figure 4.24).

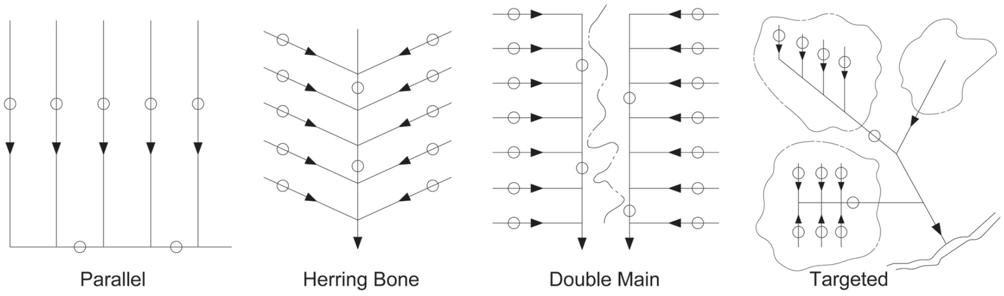


Figure 4.24 *Patterns of pipe lines in subdrains*

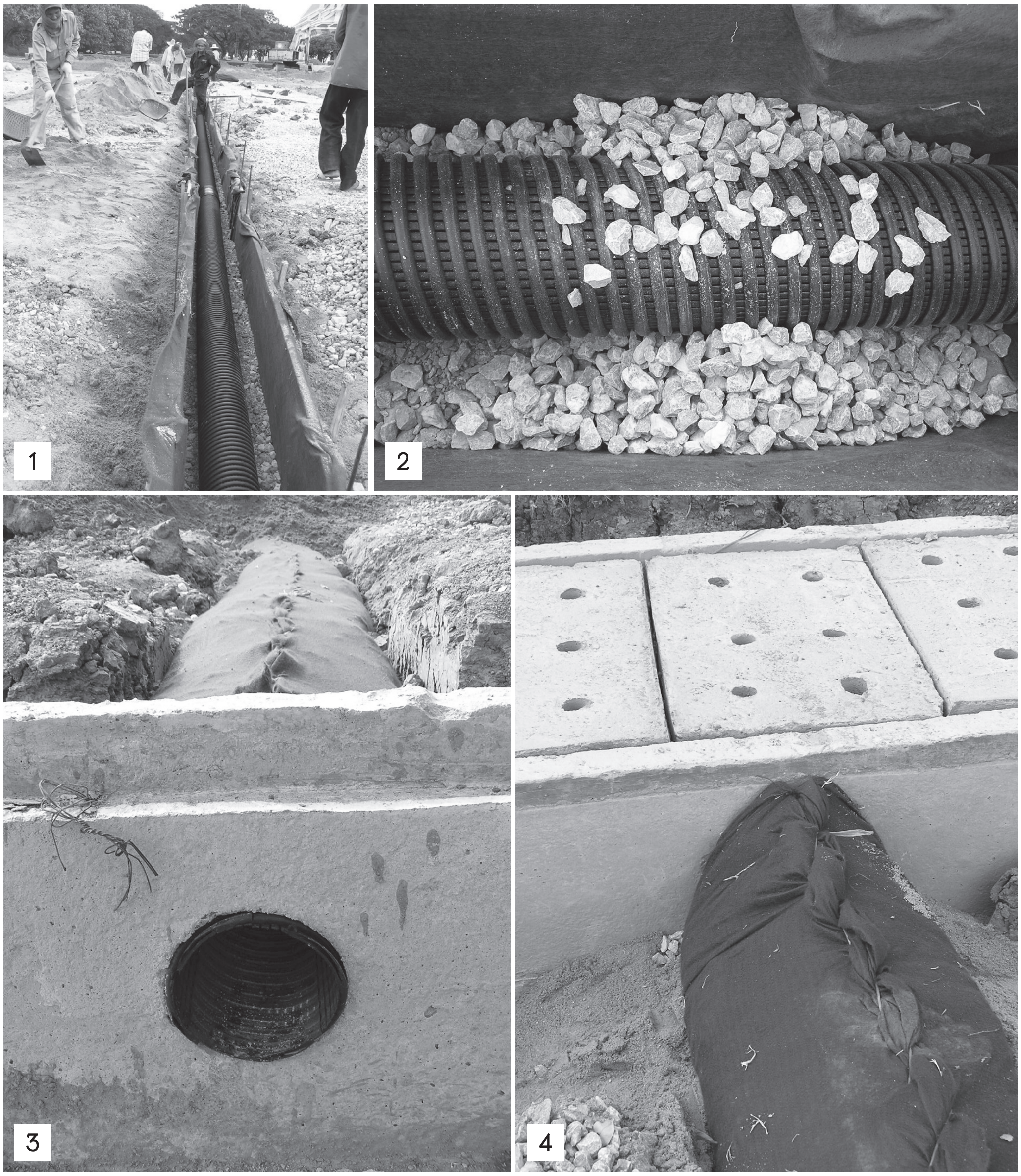


Figure 4.25 *Prefabricated subdrain system and the subdrain system in the central lawn in front of Chulalongkorn University Auditorium. Figures [1]–[4] show the subdrain system [1], by putting coarse gravel in first [2], connecting the system with the surface drainage [3], and covering it with sand and grading the surface to make sure that the end of the pipes is placed as specified [4].*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Chapter 5

Site Problems and Land Improvement

5.1 Preface

Problems in maximizing the use of an area include general problems – floods, high level of underground water, a lack of nutrients in soil and technical problems – soil erosion, soil contamination, water scarcity and air pollution. An area with such problems is usually abandoned and it is difficult to develop. The writer (2009) conducted research in abandoned areas that can be divided into many types. One is an area contaminated with toxic substances such as in Brownfield. Such areas pose problems obstructing urban development and indicating urban deterioration (Accordino & Johnson, 2000). Environmental offices in Britain use an abandoned area as an environment indicator because it is abandoned due to industrial activities or development. This area is usually related to mining and railroad construction. From 1988 to 1993, such an area was treated and reused as a recreational area or an sports ground (37%), followed by an industry site, a commercial purpose and agriculture or Temporarily Obsolete Abandoned Derelict Site (TOADs) as stipulated by Greenburg et al. (1990, 1996, 2000). The most popular term is Brownfield which refers to the use of land that was once used for activities that contaminated the site and later was reclaimed for suitable activities.

When the city expands, an open space is rare and expensive. Landscape architects and land developers have to reclaim abandoned areas to make them suitable for functional activities. For example, in Seoul, The World Cup Park is a project that turned a garbage mountain into a park, the Seonyudo public park project turned a waste water treatment plant into a public park, and in the United States, the Gas Work Park project turned a gas factory into a playgrand and public park.

Figure 5.1 *The development project in an old rail yard in Malaysia. The Sentul property development project designed by Seksan Design*

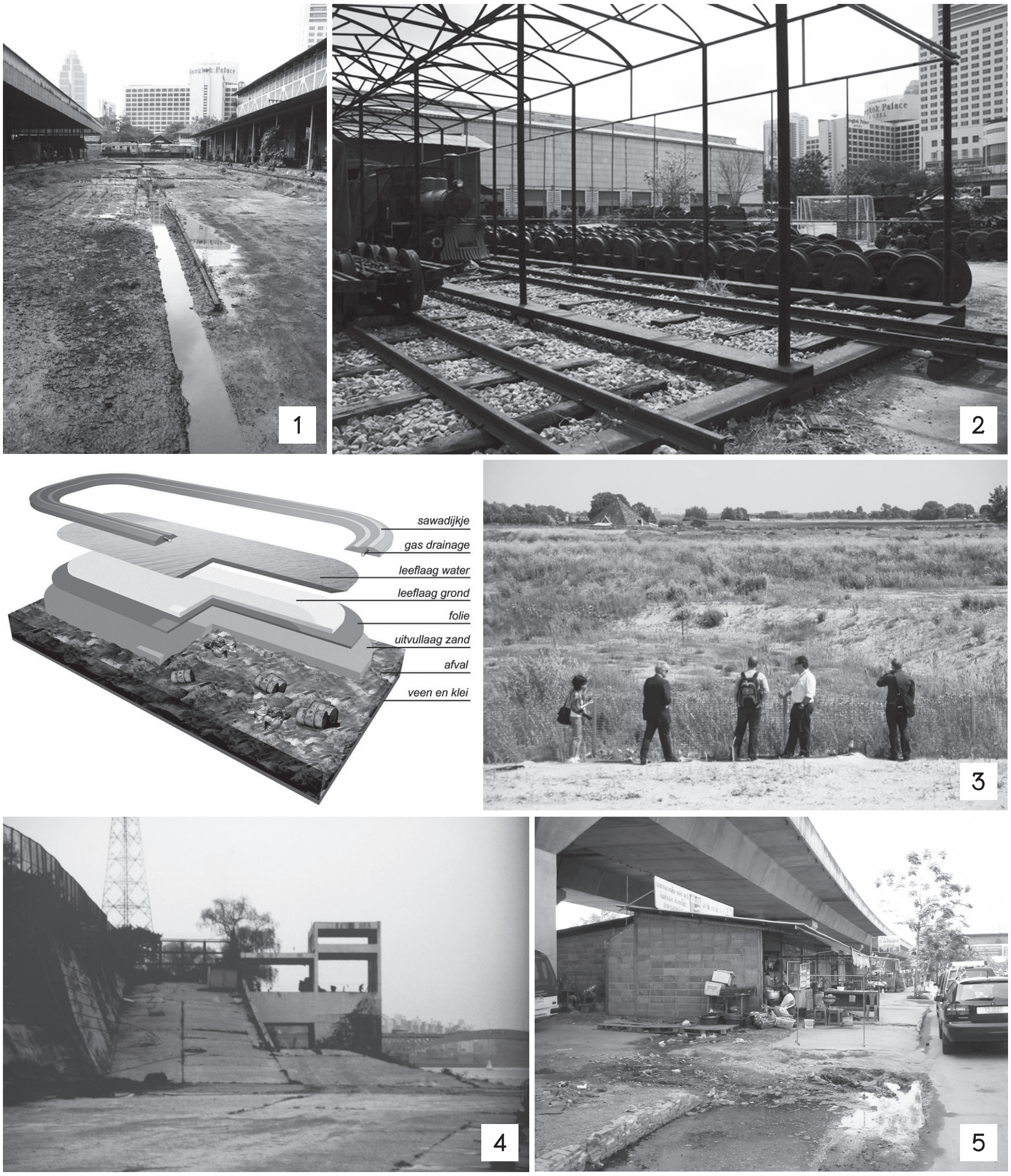
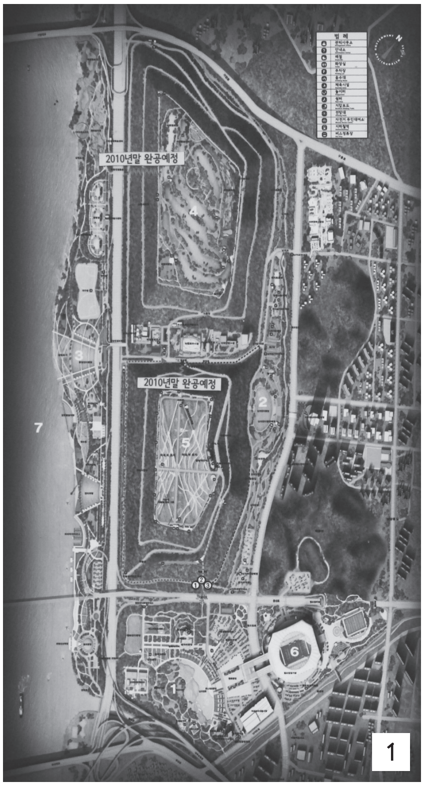


Figure 5.2 *Examples of projects that require reclamation such as areas contaminated by the train repair industry [1], [2], Afdeklagen Nieuw, a landfill, [3], a waste water treatment (before being transformed into a public park, Seonyudo) [4], a space under the expressway [5]*



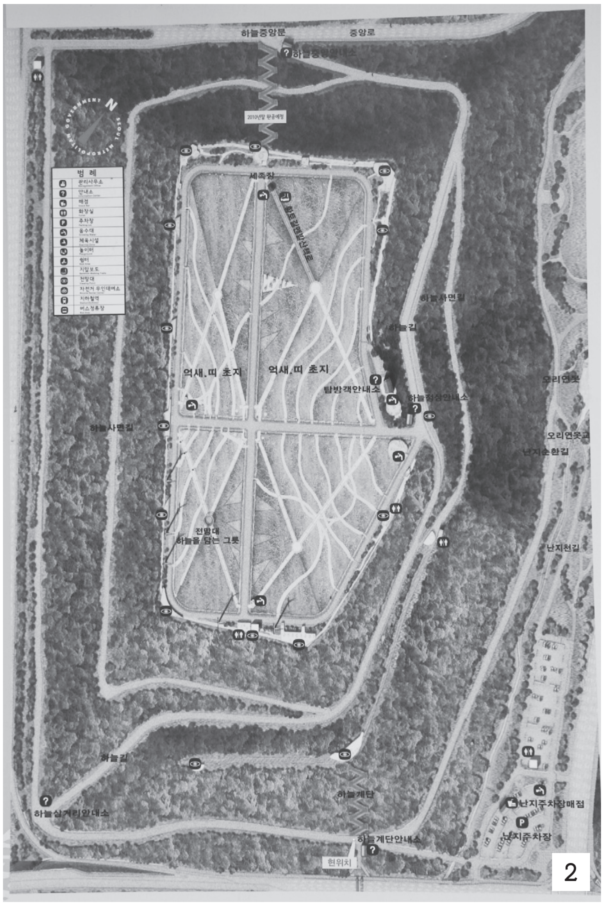


Figure 5.3 *The plan of the World Cup Park in Seoul, which used to be a landfill [1], [2] Although, the garbage site is 50 years old, a sump for wastewater and gas [3] is still needed to cope with waste resulting from the decomposition of the garbage.*

5.2 Technical problems of project sites

Before designing the land, landscape architects have to analyze the site to see what the problems and solutions are. Factors that they have to consider are:

1. **Accessibility, traffic and transportation**
2. **Existing conditions and constraints** such as buildings and trees
3. **Utilities:** tap water, electricity, telephone, waste water treatment/ waste water drainage, public drainage
4. **Floods and drainage**
5. **Soil fertility/soil conditions for planting trees:** acid soil, saline soil, depleted soil, contaminated soil
6. **Erosion:** amount of rainfall, vegetation, slope, types of soil
7. **Ecological sensibility**
8. **Noise pollution, air pollution, dust, vibration and perspective**

5.3 Analysis of site problems

Landscape architectural design involves many sciences including geography, hydrology, geology and geomorphology, ecology and environment, vegetation and botany, arts and culture, anthropology and sociology. To analyze the site problems, any research methodology of those fields can be applied.

To prevent future problems, the causes/effects of the existing problems should be analyzed and the budget used to solve such problems. The budget includes both initial and maintenance costs. If the project takes a long time to finish, strategy plans/phasing should be set up and measurements should be issued to deal with the problems. At present, there are many methodologies to choose from. Some of them are scoring/evaluation of scenarios, SWOT analysis to determine strengths, weaknesses, opportunities and threats, mind maps or problem trees if the problem solving involves many parties.

The site problems affect the site design and when the problems are dealt with, proper construction techniques can be obtained. The technical solutions to the site problems can be a flood prevention system, and fill, creating dike, digging a pond and lining, setting up utilities system, soil improvement, and weight bearing of soil, erosion control, etc.

5.4 Flood prevention

In Thailand, many communities are settled on the river banks especially in the Central Plains and most of them live their life in agriculture. Floods take place annually especially during the end of the rainy season. There is an accumulation of rain water because more water from the North flows down to the Central Plains together with high tides making drainage slow resulting in flooding. It is known that the Central Plains are flooded because of three kinds of water – precipitation, run-off and tides.

In addition to these, floods occur because of urban expansion that reduces pervious surfaces so rivers and canals have to take all the water. Nowadays levees are built along waterways to prevent flooding unlike the old days, both settlement and agriculture live together along the waterways they built their houses on stilts leaving the groundfloor free for flooding during monsoon season.

In foreign countries, they set aside some areas as flood plain or divert water from economic zone to other retention/detention areas. They prepare areas that run a risk of flooding by diminishing water level in the dam before rainy season. This involves the study of statistical data and a macro systematic land development plan.

There are many ways to prevent floods, as following;

5.4.1 Land treatment that can be done by filling with soil, sand or garbage, filling with construction waste, open dump or sanitary landfill, etc. Geotextiles can be added to support strength or sub-drains can be laid to solve the high level of underground water. The cheapest ways to protect floods are using the ditch and dike system equipped with a pump or a detention pond or a pump and a detention pond. In Thailand, the most popular is land treatment is raising the level of the land and supporting it with temporary sandbags dike equipped with a pump. The average elevation has to be higher than the level of a 100 years flood by 0.50 meters.

Other site improvement methods are included this followings;

5.4.2 Floods and floodplains. The landform and statistical data can reveal a catchment area, a basin, the divide, directions of water flow and amount of rainfall. The design of the area along the Seine River in France and that of the Han River in Seoul involve a multi-level of flood terraces (Figure 5.4). During the dry season, such areas can be used for other purposes but some areas are flooded during the rainy season.

In the past, houses along the Chao Phraya River in Thailand were built on stilts and the river banks were flooded during the rainy season. There were no levees to obstruct the flow of the water so flood water could flow in any direction. At present, levees are built to prevent floods so that more areas along the river banks can be used throughout the year. A large amount of accumulated

Figure 5.4 *The waterfront set-back area (left) in the development of the river banks in Seoul and a multi-terrace (right) to create a green area for recreation during the dry season and a flood plain during the rainy season.*

water is directed to rivers through waterways where width is limited by levees on both sides and thus flooding occurs more and more severely.

5.4.3 Dams and reservoirs along with baffle. In general, a big dam is built on high ground valley capable of retaining of water and preventing floods through proper management of water.

5.4.4 Levees-walls can be built to prevent flood. Natural Levees can also occur caused by the accumulation of sediment carried by floods. At present, a temporary retaining wall is built with modern technology like the one in Ayutthaya Province (Figure 5.7).

5.4.5 Channel alterations. These are used to increase the drainage efficiency through canals. The drainage efficiency can be increased by dredging, widening, and straightening the winding canals or constructing levees-walls along the canal banks. Increasing the slope of the river beds or lining them with concrete can expedite the flow of water. However, these alterations are not good for ecology. Today, they are improved to be environmental-friendly so called "Bioengineering", while keeping its drainage ability and problems of weeds that obstruct the flow of water can be solved by feeding the livestock with them.

5.4.6 Diversions. Suvannabhumi Airport is a case in point. The flood way runs from the north of Bangkok to the Gulf of Thailand; therefore, the airport site used to be the catchment area of more than 8,000 acres that has disappeared and blocked the flow of water. The canals parallel to the airport cannot accommodate that much water so diversions are necessary. The water is diverted to the east of Bangkok to the Bang Pakong River in Chacheongsao Province before flowing into the Gulf of Thailand.

Diversions are used when the business zone are at risk of flooding through flood diversion channels or tunnels. In Thailand, Ladpo Canal is an example of diversions. This Royal Initiative Project, helps slow the sea tides through the curvy river and the canal speed up the up north flood to the Gulf of Thailand. The King mentioned this canal during the 2005 floods, stating:

"In Pra Pradang, there is an instrument to detain a high tide and release water during the low tide. This instrument is a short cut canal. The project is initiated to release water when the tide is low and detain it flow through the river when the tide is high. If we open this 600 meters long canal, the water will rush into the lower Chao Phraya River but if we close it, the water will follow a detour. To manage the water well, we have to know when the tide is going up then let the water go, by the time it reaches the end of KlongToei, the tide will already be down" (The King's speech on December 4, 2549 at Dusitdalai Pavillion, Chitralada Palace).

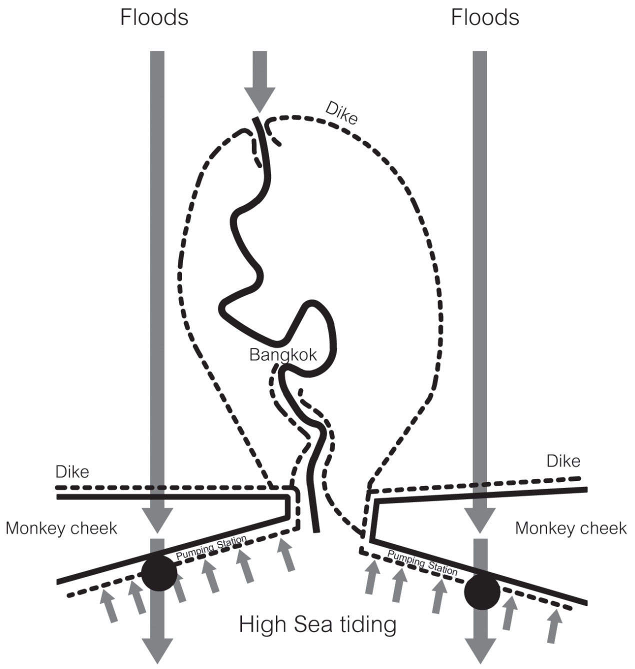


Figure 5.5 *The Royal Initiative Project on water management to protect Bangkok from floods by taking floods and high sea tide into consideration. The dikes enclose the city and there are flood ways on both sides before the water is drained or retained in the Monkey Cheeks.*

5.4.7 Detention-retention. The wet retention area is a reservoir that can hold more water than usual while the dry detention area that is not a catchment area but can become one during the rainy season. In Thailand, the Monkey Cheeks project is a retarding basin and a detention area. The King said:

> *"In general, if we give a banana to a monkey, it will peel the banana immediately then put it in the mouth and store it in its cheeks. It will do like this until all the bananas are gone or the cheeks are full. After that, it will take the banana out, chew it and swallow it."* (The King's speech on December 4, 2006 at Dusitdalai Pavillion, Chitralada Palace)

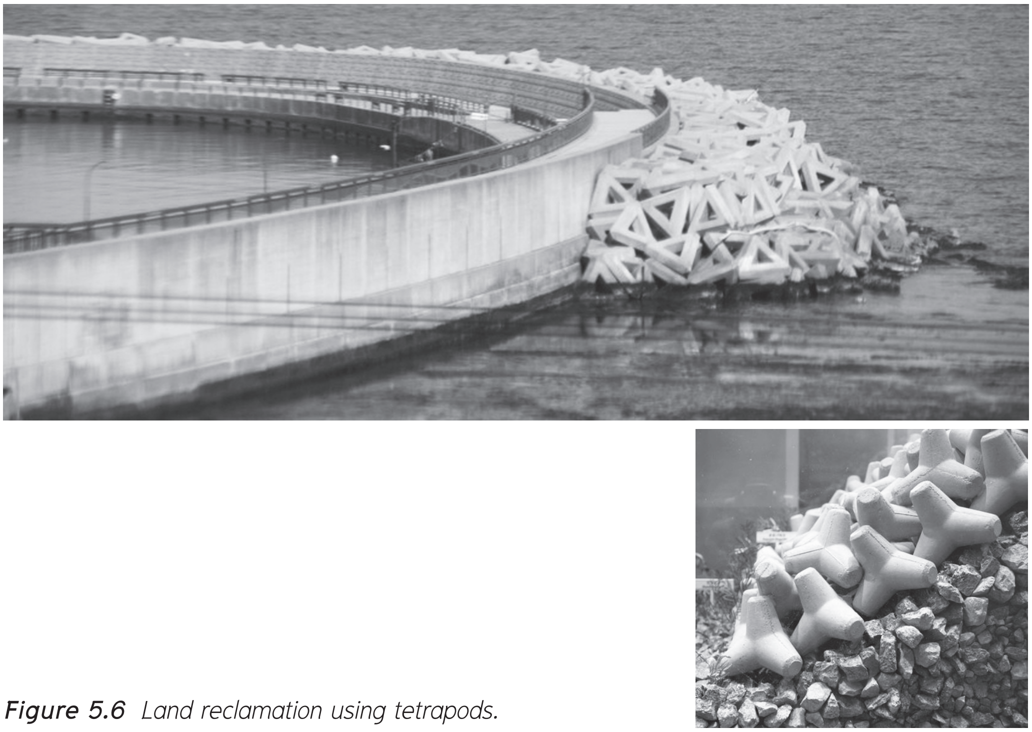


Figure 5.6 *Land reclamation using tetrapods.*

5.4.8 Sanitary landfill. The considerations of a proper sanitary landfill are:

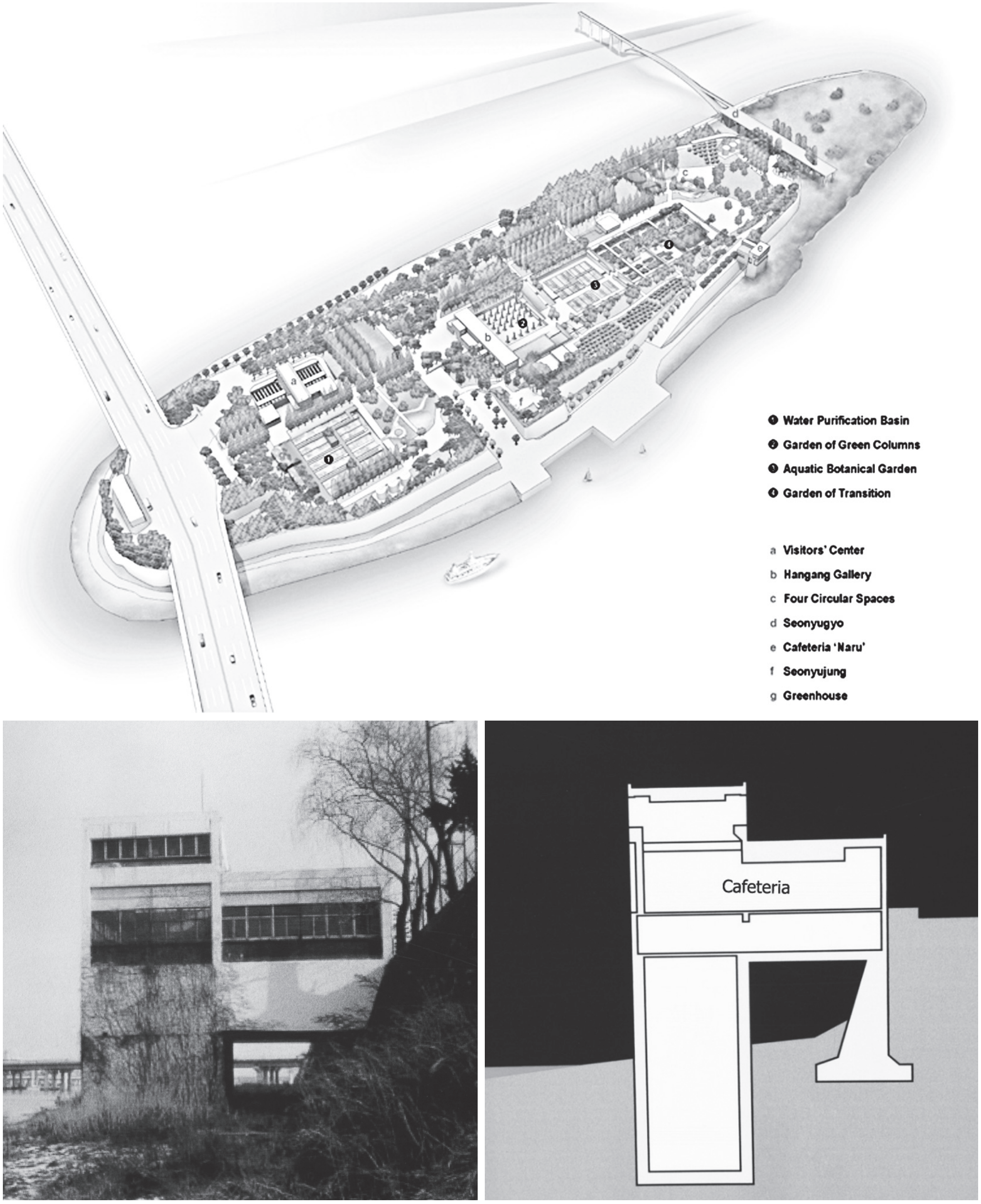
1. protect the underground water from contamination by garbage.
2. prevent foul pollution and turn garbage into fuel.
3. reduce the effects on neighboring wetland from runoff.
4. reduce timeframe.
5. utilize the project area without affecting the health of the land users.

5.5 Soil problems and improvement

Problems arise when the soil in the project area is acid soil, alkaline soil, depleted soil, saline soil or soft soil. The low land and high underground water also cause difficulties. The Department of Land Development classifies soil as follows:

1. s (sandy): the soil texture is not good and lacks a lot of nutrients for plants.
2. g (gravel): the soil contains a lot of gravel or pebbles.
3. o (organic matter)
4. a (acidity)
5. k (calcic): the soil contains a lot of lime.
6. w (water): the soil lacks water during the growing season.
7. d (drainage): the soil cannot drain water well or it is a marshland.
8. t (topography): the soil on slope or complex slope which run a risk of erosion. and is poor at holding water.
9. f (flood): the soil is flooded or soggy.
10. x (salinity): the soil is salty.
11. Others such as alkaline soils, shallow soil, peat, muck soils, and contaminated soils such as those in a Brownfield site.

Figure 5.7 *Semi-temporary flood prevention using a levee in front of Chaiwattananram Temple, Ayuttaya Province. The levee can be raised during the rainy season (above) and folded down so that the temple can be seen from afar in the dry season (below).*



The site plan and the pump house that was developed into a restaurant and a scenic point overlooking the river

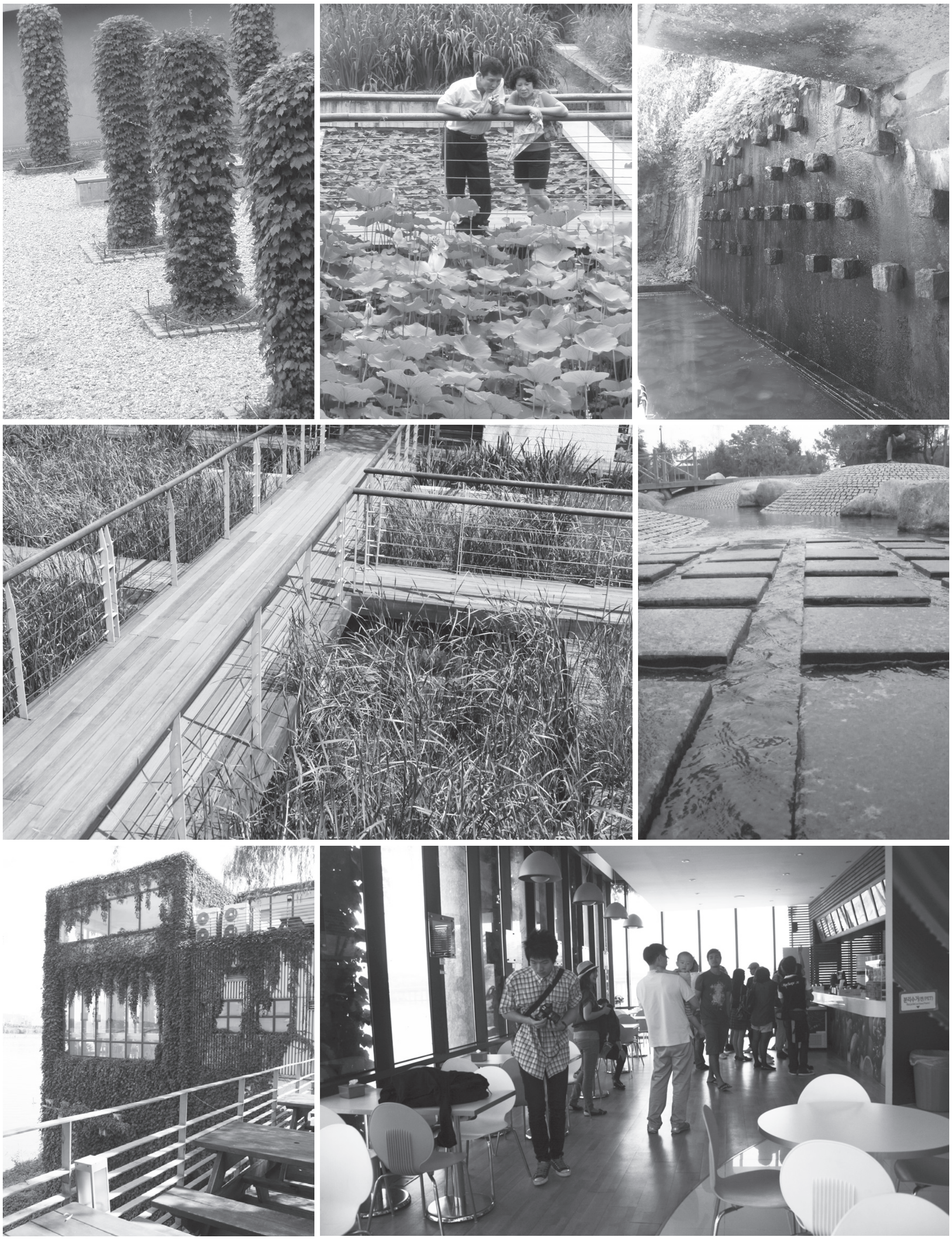


Figure 5.8 *Seonyudo Public Park, which used to be a wastewater treatment plant. This landscape architecture was recognized with the ASLA Professional Award of Merit in 2004. It was designed by SeoAhn Total Landscape.*

Sandy soil refers to the soil which contains sand with thickness of more than 100 centimeters. It is difficult to absorb water and minerals; therefore, it is not good for plants. The soil texture is compact so it is difficult for plant roots to go down. To improve it, plants should be grown at suitable interval, with organic fertilizer added and a supplementary source of water provided for the plants. If it is sandy soil with a spodic horizon, it is difficult to drain water during the rainy season and it lacks water during the dry season. It is only suitable for growing grass to feed livestock and plants like cashew nuts trees.

Organic soil refers to soil containing a lot of decomposed organic matters of more than 40 centimeters. thick. This is found in wetland with high acidity and which is phosphorus. Plants are grown on raised beds and its acidity has to be balanced.

Shallow soil. Gravel or pebbles in this soil make it difficult for plants to absorb nutrients so they grow slowly and it is difficult for plowing. This soil is found most in the northeast of Thailand. If the depth of the soil is not more than 50 centimeters,it is suitable for growing big trees along with alley cropping, grass for livestock or leaving it as it is. If the depth of the soil is 50-100 centimeters, a terrace is not suggested to solve the problem of shallow soil. If the depth of the soil is more than 100 centimeters, any measure can be applied but it should be cost-effective and worthwhile.

Non-fertile soil refers to sandy soil, soil in mines, and gravel soil that is easy for erosion. Non-fertile soil can occur from growing certain type of plant. It can be fixed by adding soil colloid and organic or chemical fertilizer to improve its water-holding capacity.

Saline soil refers to soil that contains too much salt so plants cannot absorb much water and the absorbed water is not sufficient enough so the plants eventually die. The electric conductivity of this soil is $EC < 2$ mS/cm. (micro Siemens per centimeters) or mho (micromho). It is found in areas that used to be inundated by sea water and in the northeast in Thailand. Plants that can stand salinity such as oil palm trees, coconut trees, neem trees and mangrove trees should be grown. Saline soil can be diluted by flooding it with fresh water from time to time.

Alkaline soil refers to soil whose pH is > 7. Calcareous soil refers to the soil whose pH is < 8. It lacks some kinds of nutrient but when dampness increase, its pH will decrease. It is called calcareous soil because it contains too much Na or sodic (saline) soils have pH > 8.5. Its texture is compact consisting of many nutrients but plants cannot absorb it. It can be fixed by adding gypsum and rinsing it with fresh water.

Figure 5.9 *The cross section of soil layers showing good soil (left) and shallow soil (right) with plant roots going through different layers at the Soil Museum, Department of Land Development, Thailand.*

Acid soil refers to soil whose pH is < 7 (the suitable pH for plants is ~ 5.5-7) and which contains a high level of H_2SO_4 (phosphorous acid) that is toxic to plants. It is found in Samut Prakan Province, Samut Sakorn Province, Cha-am, Bang Pakong, Bang Nam Preaw, Ong Karak, Rangsit, Tannyburi and Ayuttaya Province in Thailand. It can be fixed by adding liming materials, coarse sand and organic fertilizers.

Peat and muck soil is also an acid soil because it contains a lot of decomposed organic materials on the surface and at the depth of 1-2 meters, the soil is wet with a bluish grey color indicating that it contains a lot of pyrite (FeS_2). When the soil is dry, pyrite will react with air, releasing phosphoric acid turning the soil into acid soil. One of the King's projects, *Klaeng Din* (Trick the Soil), is a solution to acid soil.

5.6 Engineering solutions to site improvement and soil bearing

The soil in an inundated area or an area with a high level of underground water is soft and not good for bearing a heavy load. Its infiltration is not good either, leading to poor surface drainage. To make the soil bear more weight, this can be done by filling the area and compacting it layer by layer, covering it with geotextiles or other materials and using foundation piles, gabion boxes or bearing walls. A sub-drain is used to fix this problem caused by the high level of underground water.

Some low areas, with a high level of underground water and soft soil but must bear heavy loads such as the soil in Suvannabhumi Airport. There, the water is drained with the help of sand drains and rubble placed alternately then the technique of squeezing water is applied so that the soil can bear heavy loads, but it is unsuitable for growing big trees.

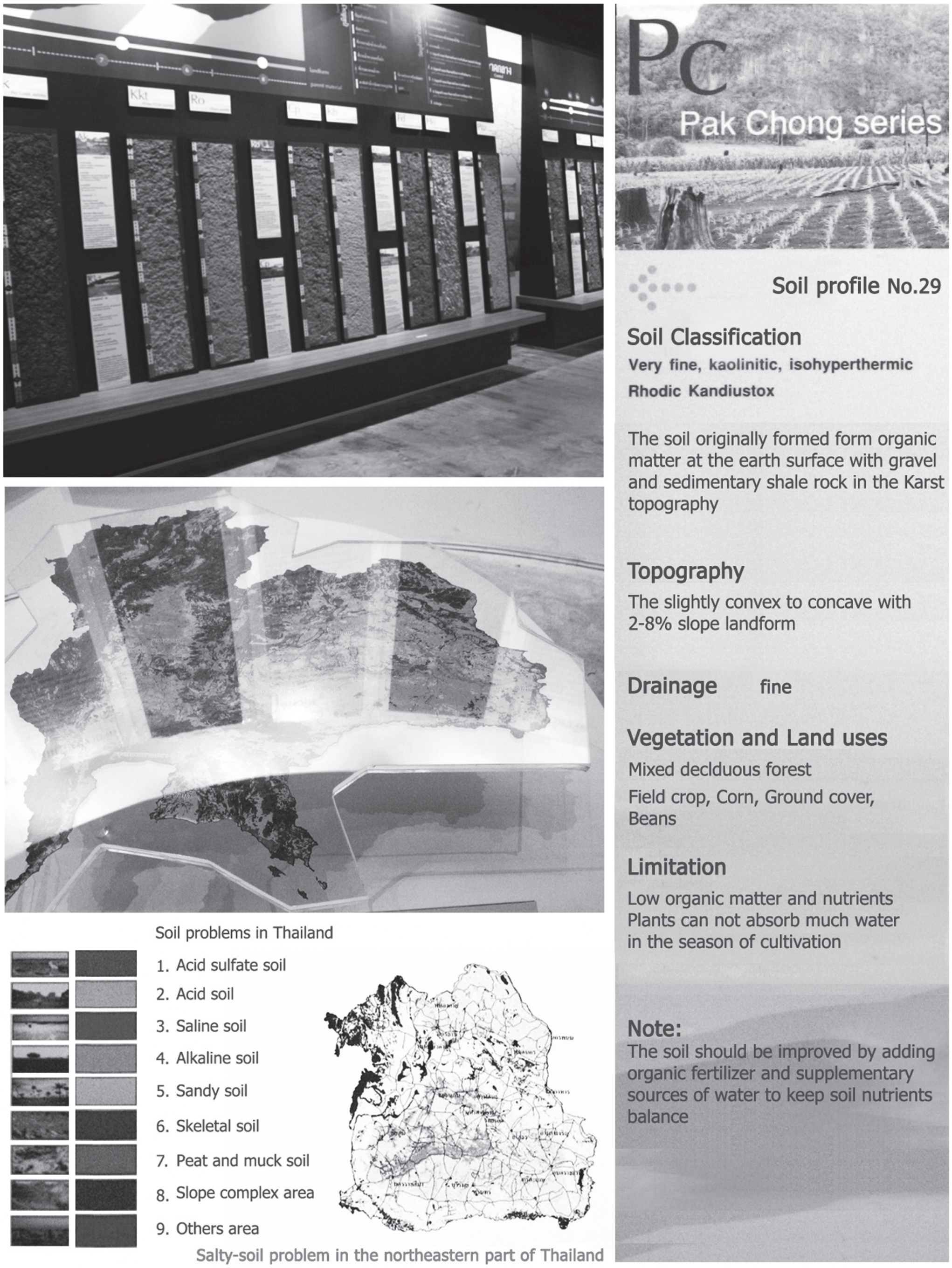


Figure 5.10 *Exhibits in the Soil Museum showing the investigation of soil and solutions to soil problems provided by the Department of Land Development, Thailand.*

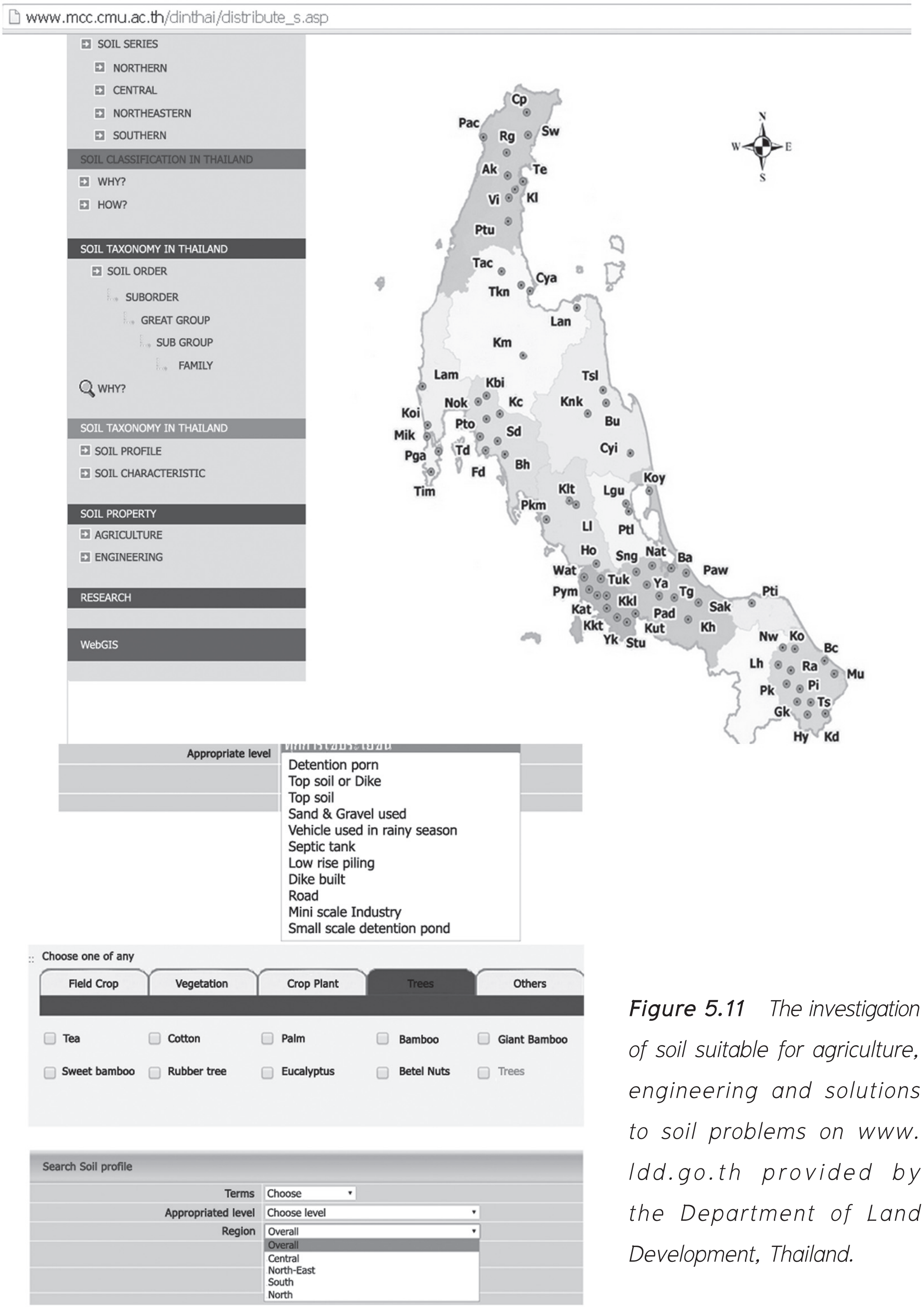


Figure 5.11 *The investigation of soil suitable for agriculture, engineering and solutions to soil problems on www.ldd.go.th provided by the Department of Land Development, Thailand.*

Source: *Erosion Control Blanket (ECB) and Erosion Control Log (ECL), products manufactured by Grasgro*

Figure 5.12 *Engineering solutions to soil erosion problems by using blanket sheets, and cushions, geo-textile materials made from coconut fiber to protect topsoil*

Saline soil improvement,
The Department of Land Development, Thailand

1. Conductivity (mmol/cm.)	2 → 4	→ 8		→ 12	→ 16	
2. Sodium (Approximately)	0.12 → 0.25	→ 0.5		→ 0.75	→ 1.0	
3. Soil salt level	Low	Mean		Salty		
4. Plant resistant	some occured	Generally occured		Salt-tolerent crop		
Crops						
Note:	Cowpea Cabbage Celery Pepper Cucumber Melon	Zucchini Sweet pepper Bean Calabash Union Corn Grape Lettuce	Cauliflower Cabbage Potato Garlic Red onion Watermelon Cantaloupe Pineapple Parsley	Spinach Turnip Tomato Cowpea Pennata	Asparagus Kale Basil Convolvulus Mangrove	Sea blite Carrissa Paper bark Alba
Flowering Plant						
	Yirbera	Rose		Golden Trumpet Gomphrena Drunen sailor Chinese Rose Paper Flower	Rosemoss Isora Chinese evergreen Portulaca grandiflora	

Source: *Saline soil improvement, recommendation from the Department of Land Development, Thailand*

Figure 5.13 *Table showing plants that can resist saline soil*

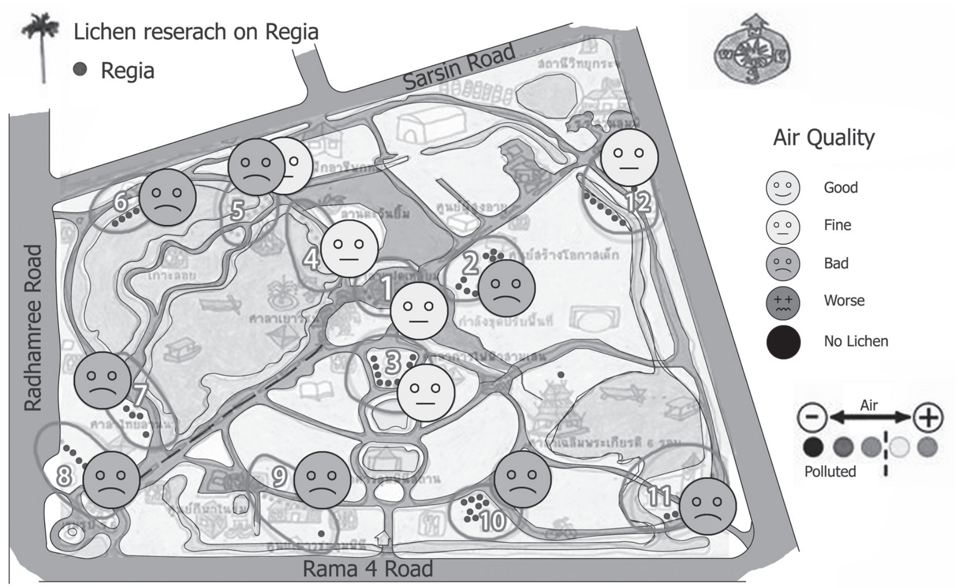
5.7 Erosion problems

Erosion can be avoided by not filling in the area too high and too steep and planting ground cover that has a long root system. Erosion, in addition, depends on the capacity and the texture of the soil, slope, types of ground cover and vegetation, amount of rainfall, floods, underground water, and wind. Landslide usually occurs due to heavy rain that is accumulated in one place until the soil in that place cannot hold the weight of water anymore. The water, therefore, carries the soil down, causing damage to the lower area. As a result, the landscape design has to analyze the risk posed by areas on the slope. The slope has direct effects on the performance of soil as follows:

- **1-3% slope**. Field strip cropping or contour cultivation should be carried out.
- **3-15% slope**. Contour cultivation, terracing or bench terrace should be carried out and the plant ridge along the dike is recommended.
- **15-35% slope**. Earth levee, bench terrace, hillside ditch or hillside terrace alley cropping should be carried out.
- **more than 35%**. It should be preserved as a source of water.

5.8 Reclamation

Problems arise from the project area such as exposure to pollutant from factories nearby can be lessened by landscape architectural measures. Although in an industrial estate, measures to control the release of pollutant and the alert notification of the high level of such pollutants are imposed, the level of accumulated pollution in neighboring communities is still high. Landscape architectural measures such as buffering and cushioning and bio-indicators helps in alleviating pollution problem.



Source: *Green World Foundation*

Figure 5.14 *The use of vegetation as a bio-indicator based on the Air Pollution Tolerance Index (APTI). Combined Energy and Wind Detective, activities organized in Lumpini Park to evaluate the quality of air through observation and study of lichen.*

1. **Buffering and cushioning** such as walls, berms, green belts or buffer zones. Growing plants with high air pollution tolerance index (APTI) is another way to reduce pollution. Such plants can be divided into four types: those with tolerant or higher index values, those with moderate index values, those with intermediate index value and those with sensitive or lower index values (Liu and Ding, 2008; Singh et al., 1991; Shannigraphi, Fukushima and Sharma, 2004). Plants that can filter air pollutions are those with broad and thick leaves such as mango trees (Shannigraphi, Fukushima and Sharma, 2004), and shrubs that have a higher APTI than perennial plants (Singh et al., 1991). Growing plants for this purpose should be in rows at different levels, and green walls can also serve this purpose.

2. **Bio-indicators**. Plants with high APTI can absorb pollution at a certain level but plants with lower index values can be used to indicate high levels of pollution. According to studies in foreign countries and in Thailand, some

lichens are sensitive to sulfur dioxide, an indicator of air pollution and some are sensitive to nitrous oxide. Increase in lichens mean levels of air pollution such as sulfur dioxide, nitrous oxide and others such as VOC decreases.

5.9 Related examples and the Royal Initiative Projects

His Majesty the King of Thailand is very talented especially in the fields of soil, water, forest and engineering. He has launched many projects to solve problems about soil, water, natural resources and the environment under the supervision of the Office of the Royal Development Projects Board, Royal Development Projects. In many regions of Thailand, there are six Royal Development Study Centers. Since 1982, more than 4,000 projects have been launched and one project related to a solution to site problems is the Monkey Cheeks Project.

The Bangkok Metropolitan Administration and the Department of Royal Irrigation classify the Monkey Cheeks into:

1. **Large Monkey Cheeks (Retarding Basin)** referring to a big pond or lake that can retain rainfall for a while before releasing into waterways. The retarding basin can be, a reservoir, a check dam or a field. Such structures can serve other purposes such as irrigation and fishery.
2. **Medium Monkey Cheeks**. This is a smaller natural pond, marsh or waterway.
3. **Small Monkey Cheeks (Regulating Reservoir)**: a smaller detention area that includes a public area, a playground, a parking lot or a lawn whose drainage system is connected to the public drainage system or waterways. The law stipulates that a retention area must be included in a real estate project.
4. **Private Monkey Cheeks**: a retention area in a private property
5. **Public Monkey Cheeks**: a retention area belonging to government offices or state enterprises

There are 20 Monkey Cheeks areas in Bangkok and its surroundings, together they can accommodate 10,062,525 cubic meters of water (Department of Drainage and Sewerage, 2007).

Thung Makham Yong, Ayuttaya Province, where the Memorial of Queen Suriyothai stands, is another Royal initiative project that detain water to alleviate flooding. The project covering an area of 70 acres can detain about 1,000,000 cubic meters of water.

Soil improvement is also carried out with the help of Vetiver grass

The grass grows very quickly and its roots are long so they can bind themselves to the soil very well. Plus, they can retain sediments carried by flooding and these sediments act like a natural levee. The grass grown in rows can slow the velocity of floods and help water to permeate into the ground.

Patterns of growing Vetiver grass

1. **On the slope**. This should be contour cultivation with a cross section the slope. The grass should be grown every 5 centimeters and 2 meters vertically between each row. Within 4-6 months, each clump will grow side by side.
2. **To control and distribute water**. Plant the grass cross sectionthe ditches or against the water flow 10 centimeters from each other and 2 meters vertically between each row. A sandbag or a rock can be placed on the grass. Flanking the levee, the grass is grown to channel the water to the field.
3. **To preserve the moisture in soil in orchards**. It should be grown when the fruit trees are young or before the trees are grown. The row should be parallel to the row of the trees or 2.5 meters away from the tree in a semi-circle form. The leaves of the grass can be used to cover the trees and become organic fertilizer for the trees.

4. **On the high ground for field crops**. Contour cultivation is advisable. It should be grown every 5-10 centimeters and compost should be placed at the bed of the ridge. It can also be grown between the rows of field crops during the rainy season.

5. **On the plain or the watershed**. It can be grown around the plantation to reduce erosion and maintain moisture in the soil.

6. **Around the pond to retain sediments**. It should be grown at the highest water mark level 1 row and 1-2 rows above the first every 10 centimeters. Dying grass should be replaced to make sure that it can retain most of the sediments and its roots can prevent soil erosion around the pond.

Growing Vetiver grass

1. To preserve soil and water

Grow it along the contour line, not more than 2.0 meters vertically between rows.

2. Two rows around the pond

Row 1: 50 centimeters from the edge of the pond and all the way around the pond

Row 2: at the entrance level of the water all the way around the pond

3. Three rows for a reservoir

Row 1: At the same level of the spillway except forthe edge of the reservoir all the way around the pond

Row 2: Higher than the first row, every 20 centimeters vertically around the reservoir except forits edge

Row 3: Lower than the first row, every 20 centimeters vertically around the reservoir except for its edge

4. One row near drainage canal: 30 centimeters from the edge of the canal

5. One row on the raised ridge: 30 centimeters from the edge

6. One row on the road shoulder

Source: *Department of National Parks, Wildlife and Vegetation*

Figure 5.15 *The planting of Vetiver grass to retain sediments and prevent erosion along the ditches*

7. **Enclosing trees half way**

A small tree: The radius is 1 meter for the distance of 3 meters

A medium-sized tree: The radius is 2 meters for the distance of 6 meters

A big tree: The radius is 3 meters for the distance of 9 meters

8. **Enclosing trees**

A small tree: The radius is 1 meter for the distance of 6 meters

A medium-sized tree: The radius is 2 meters for the distance of 12 meters

A big tree: The radius is 3 meters for the distance of 18 meters

***Klaeng Din* (Trick the Soil) Project** to solve the problem of acidic soil

This Royal Initiative Project is one of soil amendment so that plants can be grown. The sulfuric soil is “tricked” by making it dry and wet alternately to accelerate the chemical reaction in the soil – the pyrite in the soil reacts to oxygen in the air and sulfuric acid is released. When the sulfuric acid is released, the soil will become more acidic to the point, economic crops cannot be grown. After that, the soil is improved so that it is suitable for economic crops.

On September 16, 1984, His Majesty the King talked about this project at Pikul Thong Royal Development Study Center:

"...there is an experiment to increase soil acidity by draining the water and find ways to solve the problem of acidic soil. The findings can be used to help people who have this problem in Naratiwat Province. This experiment project lasts 2 years..."

Pikul Thong Royal Development Study Center conducted this experiment by

– dividing the study area into six plots. Plots 1-4 were inundated for 4 weeks and then left to dry for 8 weeks alternately. The water in Plot 5 was circulated while Plot 6 was left to nature. After that, the soil from the six plots was analyzed. The drier the soil, the more acidic it was. When the soil was inundated for a long time, or the water was circulated without being drained, the soil contained more acidity and more toxic materials.

– washing the soil and adding a small quantity of lime dust. This worked well with acidic soil. Only washing the soil was good also but it takes a longer time. After the soil was improved, plants should be grown immediately because if left unused, the soil will become highly acidic. If left to natural process, the acidic soil will improve only a little. It can be concluded that acidic soil is not useless. With soil amendment, rice, corn, nuts, sugar cane, sesame, sweet potato, vegetables, fruit trees and perennial trees and animal feed can be grown. A pond can be dug to raise fish and this can

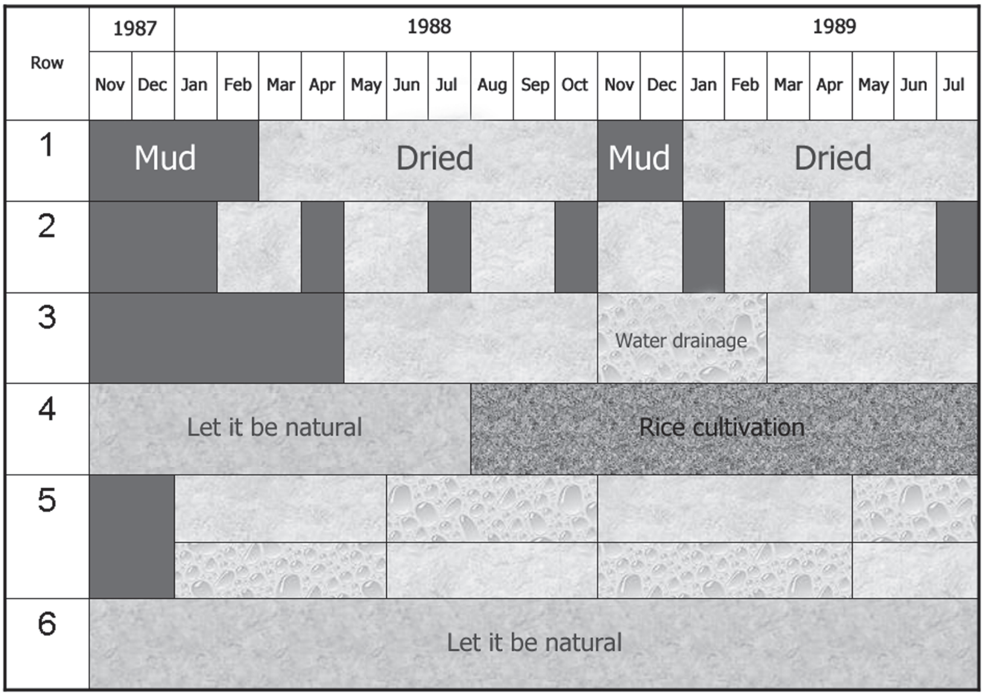


Figure 5.16 *Timetable of the experiment "trick" for the soil conducted by Pikul Thong Royal Development Study Center. The timeframe was two years (2530-2532).*

improve farmers' quality of life. They feel gratitude to His Majesty the King."

Source: ดินคือสินทรัพย์ตามแนวพระราชดำริ

(soil is an asset according to His Majesty's Initiative)

Steps of improving acidic soil after applying a "trick" to the soil

1. Control the underground water level so that its level is above mud that is composed of pyrite. The pyrite, therefore, will not react to oxygen. A proper drainage system should be installed and an irrigation system will help wash the soil, reducing the acidity in the soil.

2. Improve the soil by

– washing the soil with water. This is an easy way but a lot of water is needed.

– mixing the topsoil with lime.

– mixing the topsoil with lime along with washing the soil with water and controlling the underground water level.

3. Grade the topsoil for cultivation or use other methods such as raising ridges.

The Royal Initiative Project: **Check weir or Check dam** to restore forest areas

The main purposes of a weir are to retain sediments and water so that farmers can use this water in the dry season and forest areas can be restored. The check dam is usually made of natural materials – timber, bamboo, rocks and bags filled with earth – and its size varies. This dam can be constructed by the locals.

Figure 5.17 *A temporary weir (left) and a permanent check dam (right) to restore dilapidated forest areas in the Huay Kong Krai Royal Development Study Center. This is a center for studying the restoration of forest areas at the source of water.*

Chapter 6

Embankment: Bearing Capacity

6.1 Preface

Bearing capacity is a part of landscape architecture that involves civil engineering. Landscape architects have to have some knowledge about landform, bearing capacity, erosion, and riverbanks before being able to design such structures located near rivers. Civil engineers and landscape architects have to work closely to produce a suitable design that is not only strong but also blends in with the environment. This chapter covers the theories and examples of retaining structures, levees and retaining walls so landscape architects can apply the theories to their designs.

6.2 Embankment

Failure of an embankment results from current flow, water level, height of bank, function of bank and bearing capacity; as a result, to protect the bank, all these factors have to be analyzed. Failure of an embankment can be classified as:

1. Shallow failure
2. Planar failure, block failure
3. Rotation failure
4. Failure in composite banks

An insight into these failures will enable landscape architects to incorporate civil engineering concepts into their design to protect the failure of the embankment.

6.3 Toe protection control

Protection of the toe from being eroded by base flow can be done by using an impervious cut-off wall, constructing revetment down to the riverbed or using an armor skirt or apron.

6.4 Components of embankment construction

The embankment structure consists of three parts.

Part 1: Crest

Part 2: Revetment

Part 3: Toe

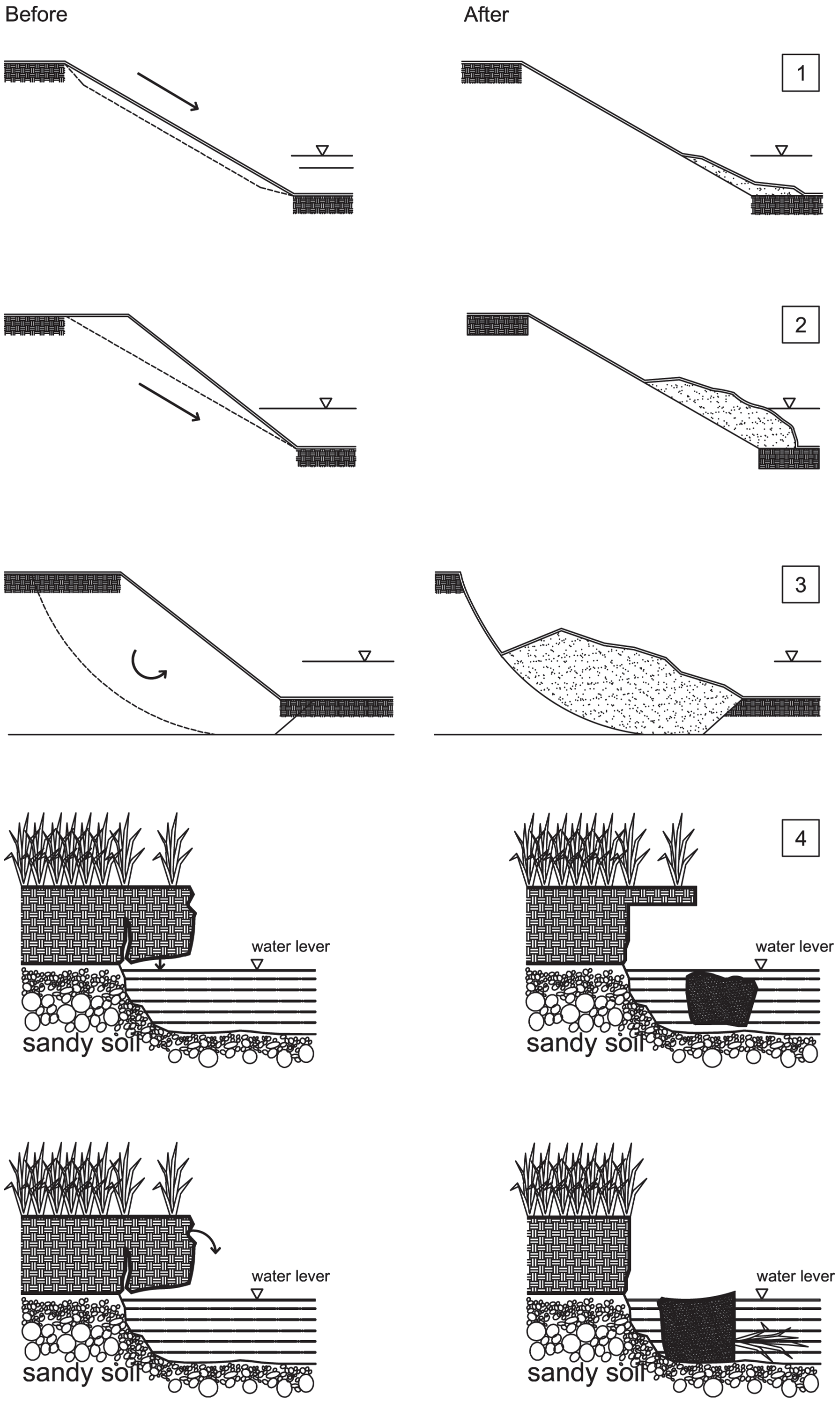


Figure 6.1 *Types of failure of embankment, before and after of failure. From top to below: shallow failure [1], planar failure [2], rotation failure [3] and failure in composite banks [4]*

6.5 Types of embankment

The Department of Public Works and Town & City Planning (2009) classifies channel bank armor in Thailand into the following eight types:

1. Rock riprap with high bank
2. Rock riprap with low bank
3. Rock riprap with gabion box
4. Rock riprap with gabion box and retaining wall at the crest
5. Rock riprap with foundation piles and anchorage at the crest
6. Rock riprap with foundation piles and tie rod and anchorage at the crest
7. Batter piling channel bank armor
8. Platform piling channel bank armor

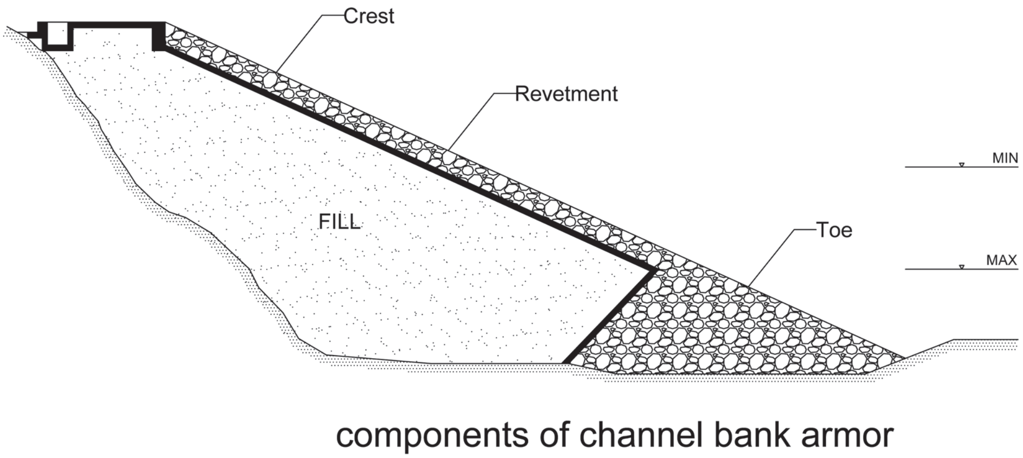
There are other kinds of channel bank armor that cannot be clearly identified in terms of civil engineering but they can prevent bank erosion such as a combination of the riprap and natural method, sand-cement bag revetment, dead trees, and tile channel bank armor when the bank is less than 2 meters high.

The structure of channel bank armor affects landscape architectural design as a whole so landscape architects have to study the armor and the retaining wall carefully so that they can integrate this knowledge into landscape architecture. The types of retaining wall are as follows:

1. Masonry, gravity, semi-gravity (reinforced) wall
2. Dry stone/boulder, rock-filled buttress
3. Cribbing: gabion box, timber, vertical interlocking block, metal bin, waterbreak block wall
4. Cantilever wall
5. Counterfort wall

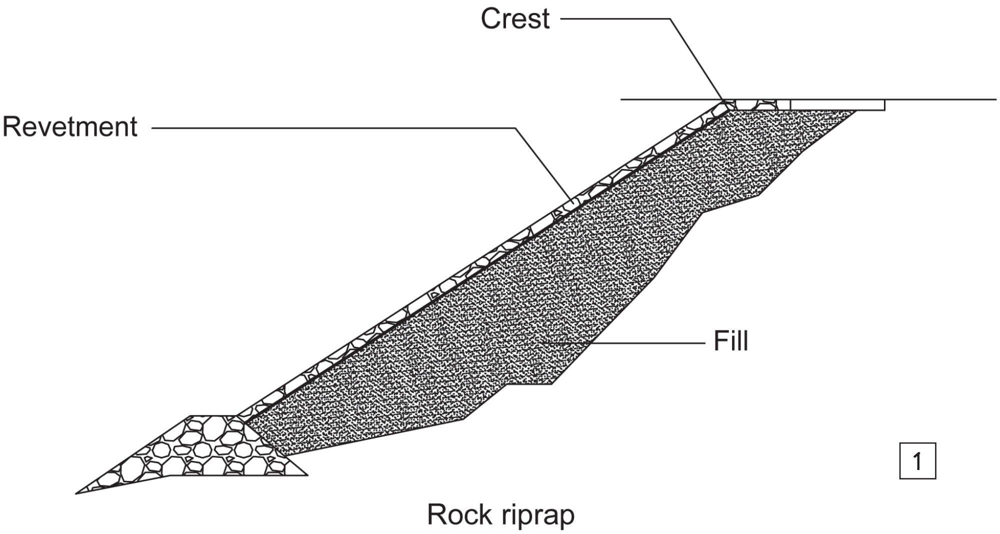
6. Anchored curtain wall
7. Sheet piles

Landscape architecture can incorporate both channel bank armor and retaining wall in design. For example, gabion baskets/gabion box made of coated wire, rip-rap and water break can be used for other purposes besides preventing bank erosion. Sand-cement bags can replace rip-rap. Water break can hold and resist water flow and it comes in many forms. A tetrapod is the most popular form and its crest can be decorated to appear like a natural structure.



Source: *Department of Public Works and Town & City Planning, Ministry of Interior*

Figure 6.2 *Components of channel bank armor*



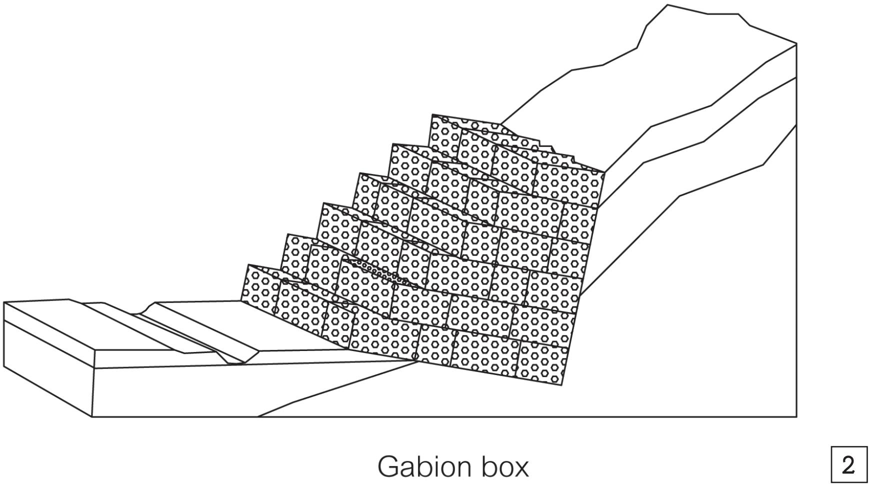


Figure 6.3 *Rock riprap [1], gabion box [2]*

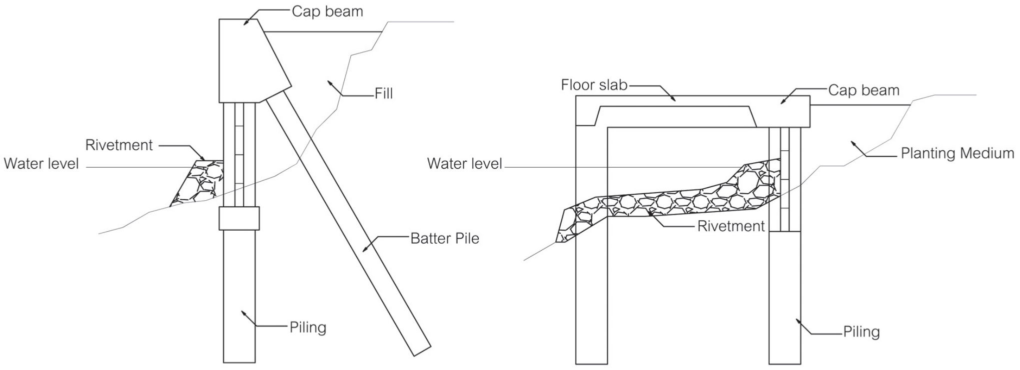


Figure 6.4 *Batter piling channel bank armor (left) and platform piling channel bank armor*

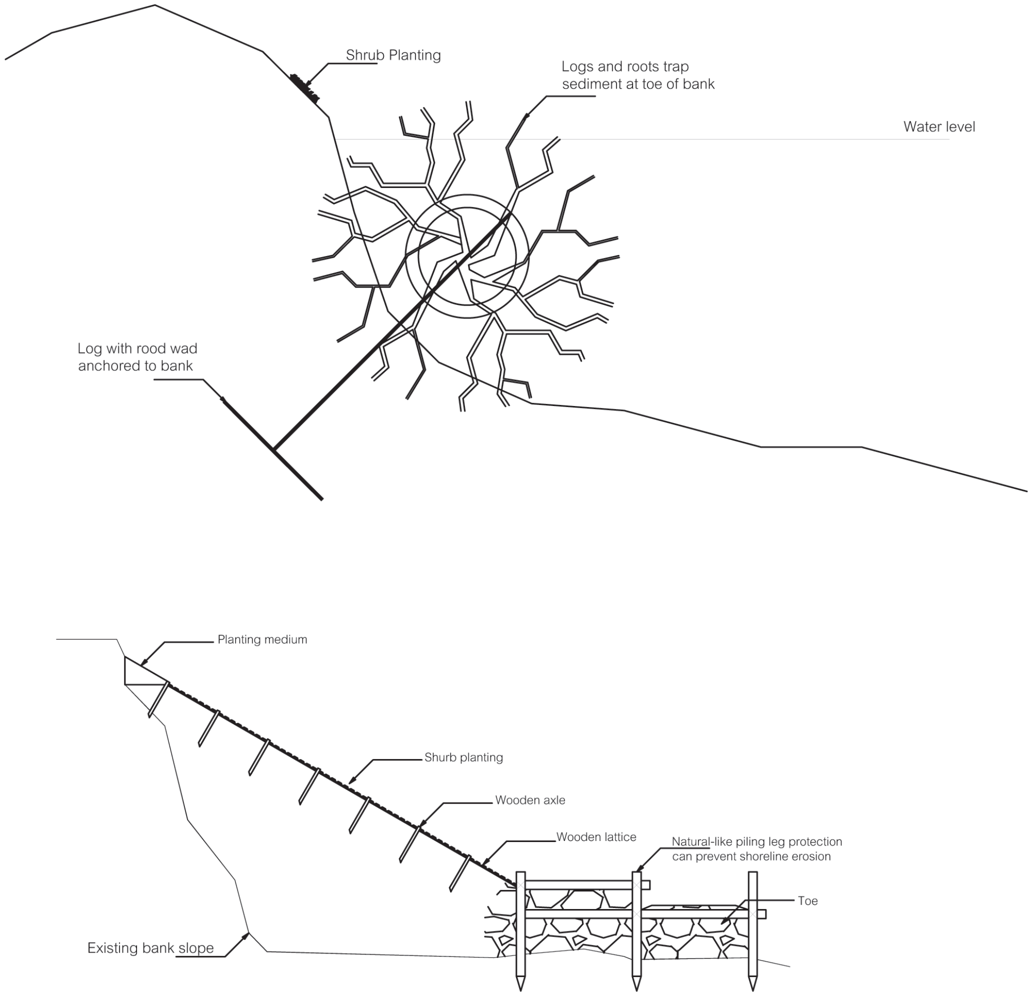


Figure 6.5 *Natural-like channel bank armor*

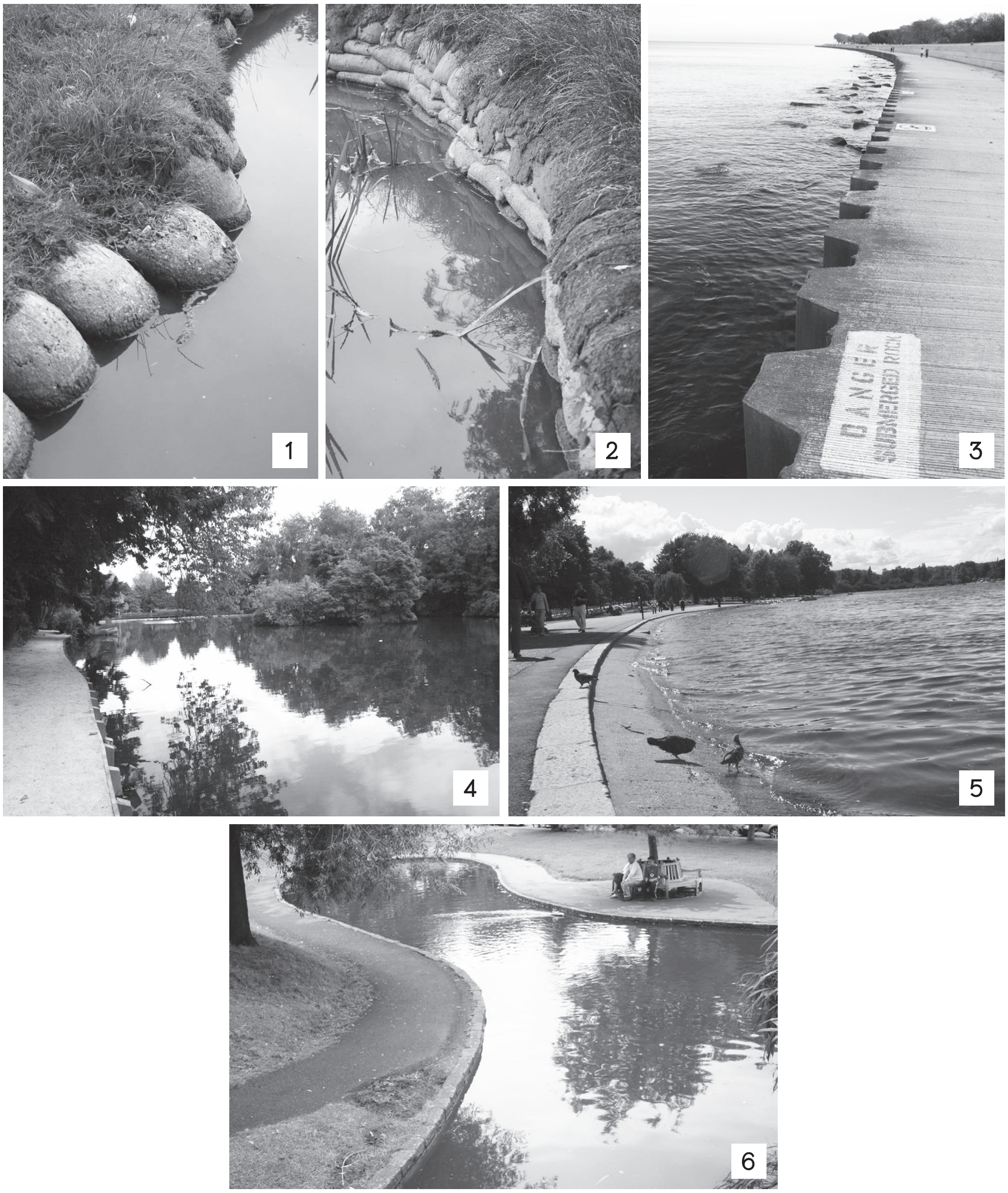


Figure 6.6 *Types of river bank*

1. *Rip-rap*
2. *Sand-cement bags*
3. *Sheet pile in Michigan Lake, Chicago*
4. *Wooden pile and vertical bank of shallow pond*
5. *Slope bank. The water can be accessed easily.*
6. *Vertical bank*

6.6 Types of coastal protection

The Department of Public Works and Town & City Planning has compiled ways to construct and control construction of protection structures along the rivers and coasts. The structure also change the physical conditions of the coast so as to protect the coast from erosion by waves and wind. The coasts of Thailand – the Gulf of Thailand and the Andaman Sea – are all facing severe erosion caused by:

1. The use of coastal areas.
2. The depletion in mangrove forest, which is a natural buffer.
3. Land development by filling the sea or constructing large structures in the sea that affect the directions of the waves and sand.
4. A change in water channels resulting from the construction of dams, check dams or sand digging, leading to an imbalance of sediments at the estuary.
5. High and low tides and the influence of monsoons.
6. The geomorphology of coastal areas such as sandy beaches, muddy beaches, boulders and coastal slopes.

Coastal protection structure can prevent shoreline erosion. Both designing a suitable structure and maintaining it are important and engineering knowledge is required. However, the design, materials, construction techniques and construction time vary. The materials can be large rocks, geotextiles, reinforced concrete, concrete, gabion boxes, or wire-box mattresses.

At present, gabion boxes and mattresses are more popular and their advantages are as follows:

1. They are flexible but strong in bearing capacity and water current.
2. They can absorb water well so there is no pressure from underground water.
3. Their sturdiness, and efficiency in resisting force improve as time goes by due to the accumulation of soil and sand in the box.
4. They are cost-effective.
5. They can blend in well with the surroundings and trees can grow on them.

The structures to prevent coastal erosion are sea walls, T-groins, interlocking concrete blocks, tetrapods, three-tiered triangular wave breakers, *Khun Samut Cheen* 49A2 (designed by Professor Dr. Thanawat Charupongsakul) and sand sausages.

Figure 6.7 *Types of protection against shoreline erosion*

1. Embankment using interlocking concrete blocks

2., 3. Tetrapod sea wall in Central Air Airport, Nagoya, Japan

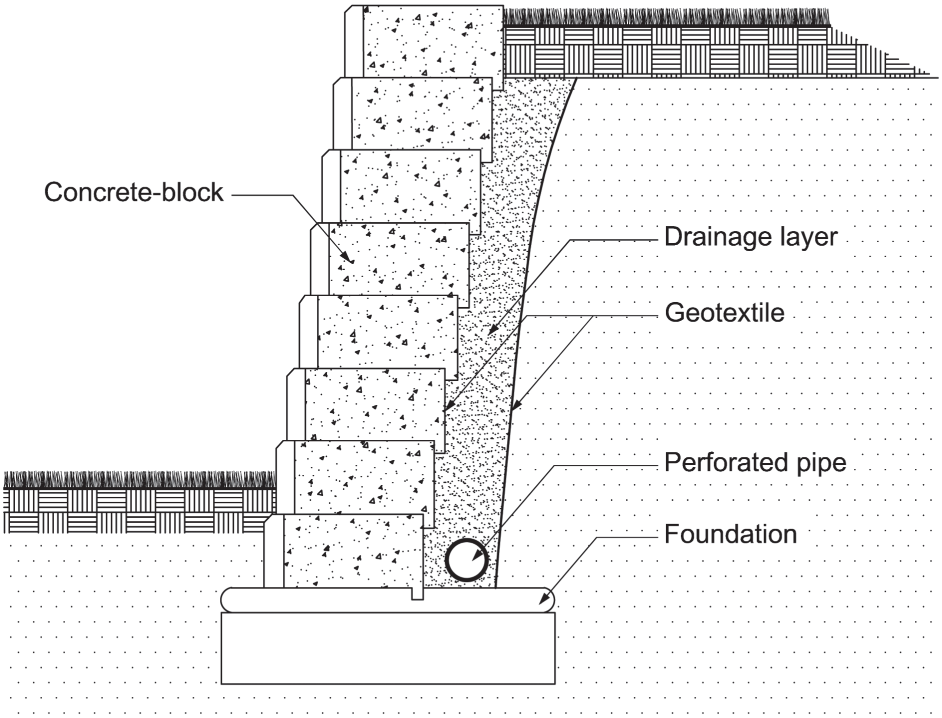
4. Electric poles and tires used to absorb oncoming waves in Bang Pu beach, Thailand.

6.7 Retaining wall and bearing wall

In engineering, one structure built to prevent bank erosion and shoreline erosion is the retaining wall. At present, the gabion box is used to prevent bank and shoreline erosion in addition to concrete and concrete blocks. Counter forts, buttresses, sheet piles, batter piles and tie rods and anchorage can be added to the structures to support them because they have to resist the force on one side only.

The components of the retaining wall are:

1. A toe that is usually found in the cantilever wall, and the soil on the toe will stabilize the wall.
2. A backfill that can be sand, gravel or crushed rock.
3. A batter front.



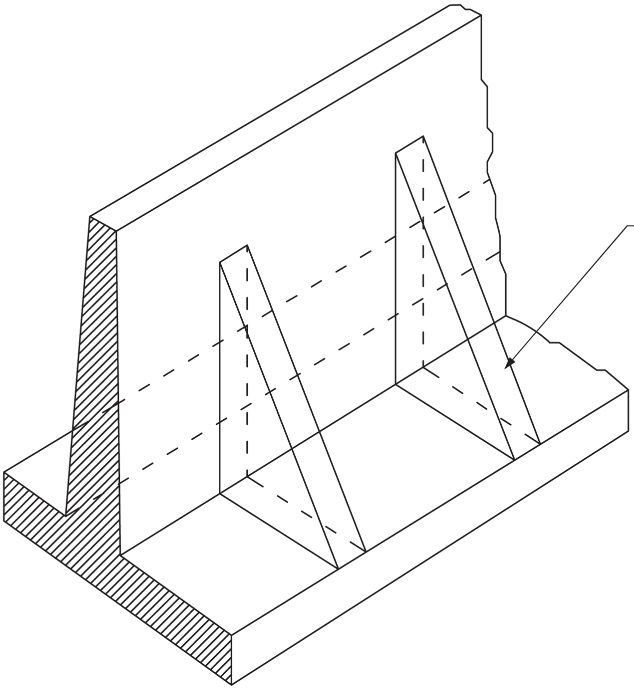


Figure 6.8 *Concrete-block retaining wall (left) and counterfort retaining wall (right)*

Figure 6.9 *Retaining wall made of natural materials such as wooden posts made into a box for holding rocks; as a result, vegetation or weeds can grow on it*

Figure 6.10 *Structure built to prevent soil erosion on the slope and which is supported by vegetation*

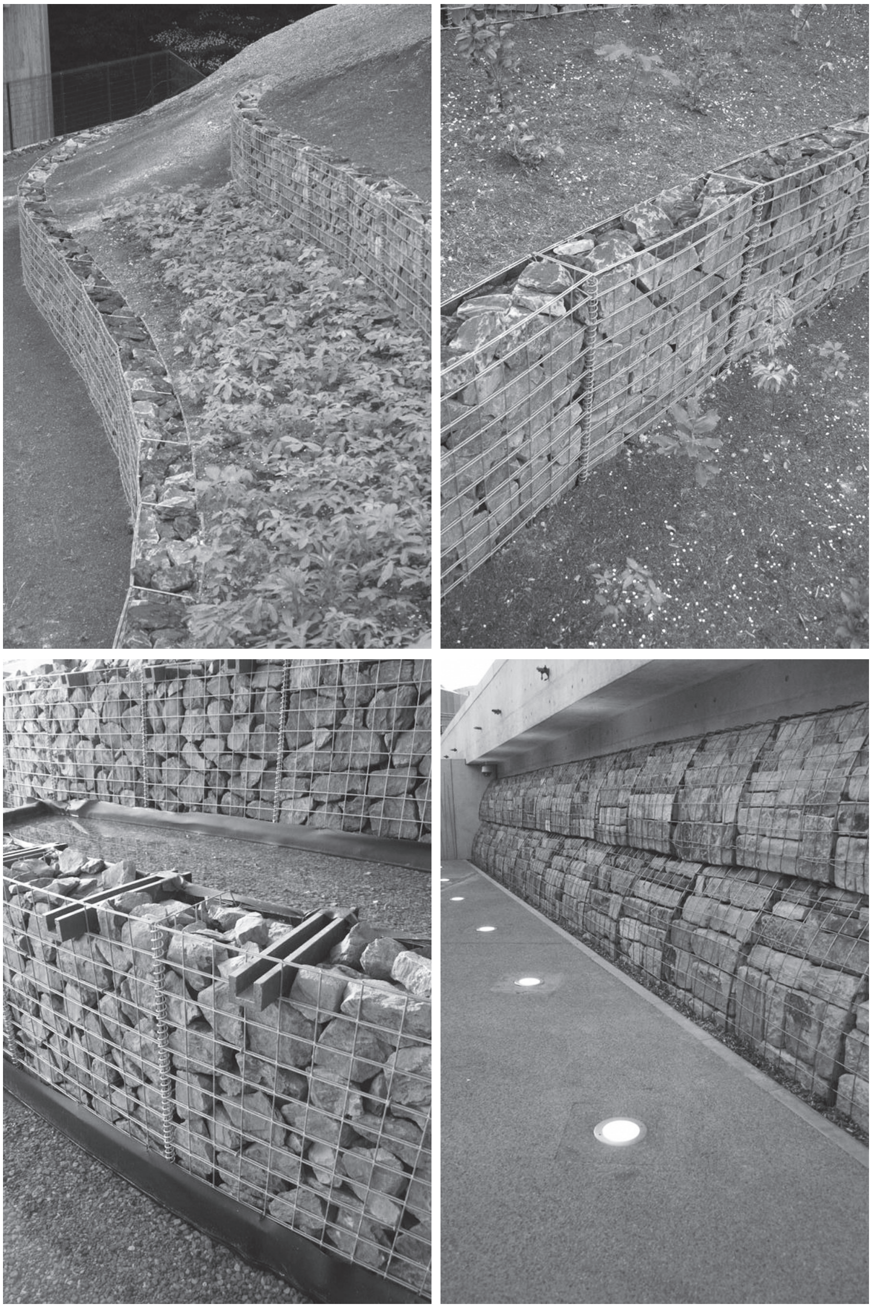


Figure 6.11 *Modified gabion box to be used in landscape architecture to maintain its natural scenic beauty*

Lakes in Windermere District, UK. whose ecology varies according to depth

Chapter 7

Natural Ponds

7.1 Preface

Chapter 7-10 deal with water in terms of drainage, natural ponds, artificial ponds and fountain/waterfall systems, waste water treatment and landscape irrigation/watering systems. Water is an important factor to be considered when designing a project area. Ideally, natural water resources should be kept intact and maintained. Without maintenance, the water quality will decline become and polluted, threatening the environment, living organisms and land use.

7.2 Types of water sources

Aquatic habitats can be divided into marine, estuarine, and fresh water habitats. The salinity of a fresh water habitat must be less than 0.5 ppt while that of a marine habitat must be more than 20 ppt.

Water sources can be divided, according to the flow, into:

lentic/standing water = limnology, hydrology

lotic/running water = potamology

Surface water sources are termed as follows:

A lake is a big natural water source that can be either a fresh water lake or a salt water lake. It is deeper than the shoreline. There is usually a channel for water to flow in and there is water all year round and the water level does not differ much during the year.

A swamp is a low area with water, smaller than a lake and not as deep as lake. Vegetation grows in the swamp. One example of a swamp is Borapet Swamp.

A marsh is wetland where only reeds can grow. It is a shallow body of water with gentle slope. There is no chanel for water to go in and out of the marsh. During the rainy season, The area is large but during the dry season, it decreases and becomes shallow. Nong Prachak and Nong Han are examples of marshes.

A pond is a small and shallow man-made water source. The slope of the edge is steep and the amount of water varies according to the season. The water is for consumption.

A reservoir is a large man-made water source to obstruct the water flow of a river or a stream. If a reservoir is built between valleys, it will be very deep with steep slopes.

Standing water sources can be divided into zones based on depth and exposure to sunlight affecting living organism and ecology. To develop this area, preserving the ecology is an important issue. According to academic documents, the division of zones of standing water source is based on the growth of vegetation and the distance away from the river bank or the depth of the water source that sunlight can reach for photosynthesis to take place. It can be concluded that standing water sources can be divided into five zones.

1. **Littoral zone** – Area where Sunlight can reach the ground. A lot of aquatic plants grow here and most of them are submerged plants such as Hydrilla verticillata, an algae. This is a plant which grows well in that has good accessibility to sunlight shallow water. In addition, this zone is teeming with aquatic animals that are part of the food chain. The plants and animals are diverse here.

2. **Limetic zone** – An area of water that is further away from the showing. The depth of their area is determined by the depth that sunlight can reach. It is the depth that amount of oxygen produced from photosynthesis equal oxygen used in breathing. This is called compensation depth, an area where the intensity of sunlight is 1% intensity of sunlight at the water surface. There is enough photosynthesis for plankton which is an important food source for small fishes.

3. **Euphotic zone** – From the water surface to the area where there is enough sunlight for photosynthesis. It is vertical limnetic water column.

4. **Profundal zone** – Sunlight cannot reach this area. It is very dark so plants and plankton are not found. Sediments are piled up in the river/sea bed and most aquatic animals here subsist on decaying food and are well-adjusted to the darkness.

5. **Benthic zone** – The river / sea bed where no living organism but dead aquatic animals and plants are found.

Lothic/running water sources include rivers, streams and canals. A river refers to a big water channel where there is water all year round. The water flows from upstream into the sea. Upstream, water flows in the same direction until it reaches estuary, and then the water flows into two directions – up and down according to high tide and low tide. The river is composed of four main parts.

1. A watershed area where water is collected.

2. A stream acts like a chute and is usually found in a gap, hill or high ground. It is not very wide and the soil at the bottom is sandy. Streams can be divided into:

a. Permanent streams. Overland runoff is collected here during the rainy season but during the dry season, underground water feeds this stream.

b. Intermittent streams. These have water only during the rainy season. The soil in the riverbed is sand or gravel.

c. Interrupted streams. At certain point the water flows into the ground so the stream disappears and emerges further away. It is usually found in a desert or a limestone mountain.

3. Rivers. Water is here all year round and a rock, gravel and sand are found in the upper front of riverbed. The width of the river is wider and widest at the estuary.

4. Flood plains. These are basins along the river banks and are inundated during the rainy season. The Central Plains and Ayuttaya Province are examples of flood plains.

Canals and ditches are water channels that are not very wide. Can join together to form a network or flow in together to form canals and ditches rivers or standing water sources.

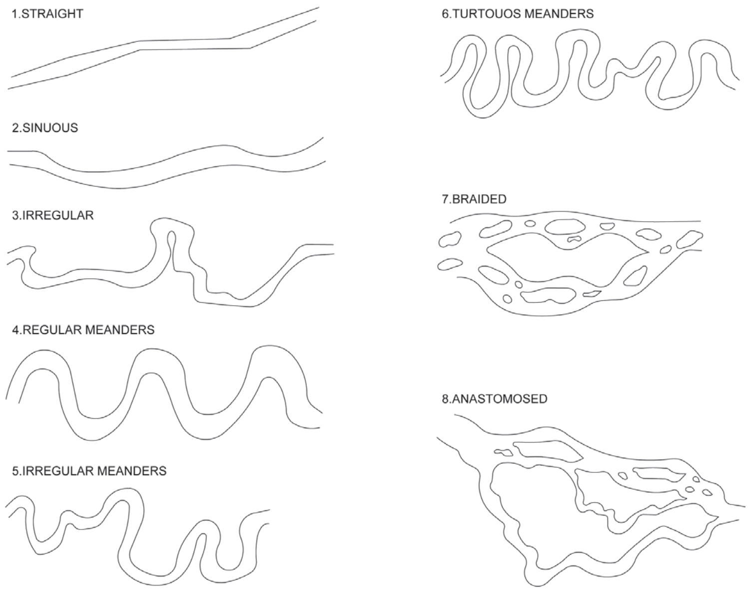


Figure 7.1 *The water flow winding along the shapes of canals*

The flow of water in rivers – streams

1. Turbulence. The water flows in different directions and the water surface is not smooth.

2. Laminar. The water flows in the same direction and the surface water is smooth.

The measurement of water movement can be done in two ways flowing – flow velocity and water discharge. Flow velocity is the velocity of water from one point to another which varies depending on factory such at groove, V shape or U shape, the slope of the river, riverbed and depth. The water discharge is the amount of water flowing from one point to another in the groove per unit of time. Mostly, the unit is cubic meters/minute.

7.3 Types of wetland

A wetland is an ecologically fertile area. Thailand is one of the 160 country members of the Ramsa Convention on Wetlands, 2011, whose main purpose is to preserve wetlands and guide their sustainable use. Wetlands can be divided into the following:

Peat is composed of acid soil. The inundated peat area is called mire.

A marsh can be either a fresh water marsh or a salt water marsh. The main characteristic is that it is an open space with small vegetation. Peat may not build up here.

A swamp has more trees than grass or weeds. This term is used in tropical areas and in North America. The soil and the water may be acidic. A fresh water swamp does not have an accumulation of dead plants and organic materials and the water comes from rivers or big swamps. Sparse forest is found here and the trees do not have clear tree rings.

A bayou or slough is a water channel that passes a marsh or swamp. Sometimes it is called a creek.

A pocosin is like a bog because there are bushes and trees that can resist fire. They are found in the southwest of the United States.

A fen is a fresh water bog and the underground water is alkaline. This means that the ratio of hydroxyl charge is medium to high (pH is more than 7). A carr is a kind of fen that has been improved until plants can grow there. Carr is a term used in northern Europe.

A bog is a wetland that is inundated and which has a lot of decaying trees and vegetation. When one steps on it, one will sink. Layers of peat are found in this area and there are no rivers or canals running into this area. The primary roots of trees here are short while their secondary roots expand and are strong. Trees like Calophyllum inophylloides, Baccaurea bracteata and Blummeodendron kurzii have stilt roots. Some have buttresses and some have breathing roots or pneunatophores emerging from the ground. Some of these roots look like a bending knee, an arch bridge, a semi-circle or a winding wooden board.

According to Cowardin's wetland classification, wetlands are classified based on ecoregion of vegetation ranging from the least complex to the most complex type (Cowardin et al., 1979).

1. Marine system. The vegetation is the least complex.
2. Estuarine system. The vegetation is more complex than that of the marine system.
3. Riverine system. The vegetation is averagely mature.
4. Lacustrine system. The vegetation is nearly as complex and mature as that of the palustrine system depending on the age, the depth and the location.
5. Palustrine system. The vegetation is the most complex and most mature.

7.4 Factors affecting design/ecological factors affecting wetlands

The factors that affect wetland development design are landform, soil property, infiltration capacity, vegetation, climate, animals, natural disasters, culture (social factor), esthetics, ponds (as a producer). The natural and ecological factors that affect wetlands are temperature, amount of oxygen, sunlight, waves, winds/storms, strata of living organism and depth.

The depth of a lake is also important in terms of ecological system; therefore, lakes can be classified into four types depending on depth – epilimnion (surface water or the first layer), metalimnion (the second layer), hypolimnion (the third layer) and monimolimnion or the bed). These layers are related to the classification of water sources according to the amount of sunlight and oxygen that influence the water temperature and living organisms at certain depths as mentioned earlier.

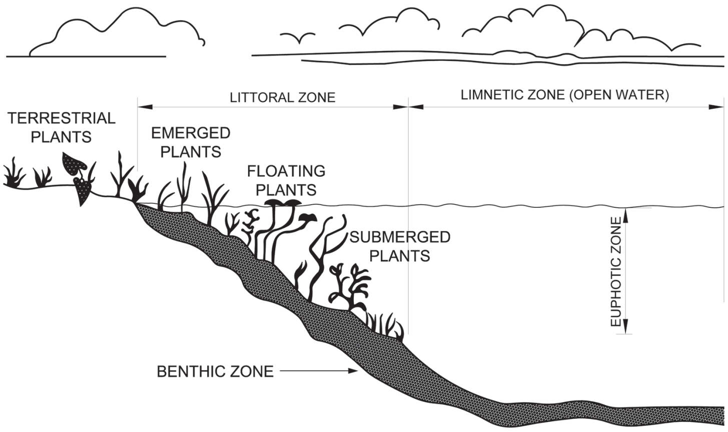
Littoral/limnetic trophogenic – The area that requires sunlight and oxygen

Profundal – The area between the shoreline and the benthic/tropholytic

Benthic/tropholytic – The area where living organism can thrive with little sunlight or oxygen.

Changes in lakes and wetlands can be caused by ecological factors (natural eutrophication) and by cultural eutrophication. Cultural eutrophication includes water drained from:

1. Agricultural and livestock raising areas.
2. Industrial areas.
3. Urban areas.
4. Residential areas.



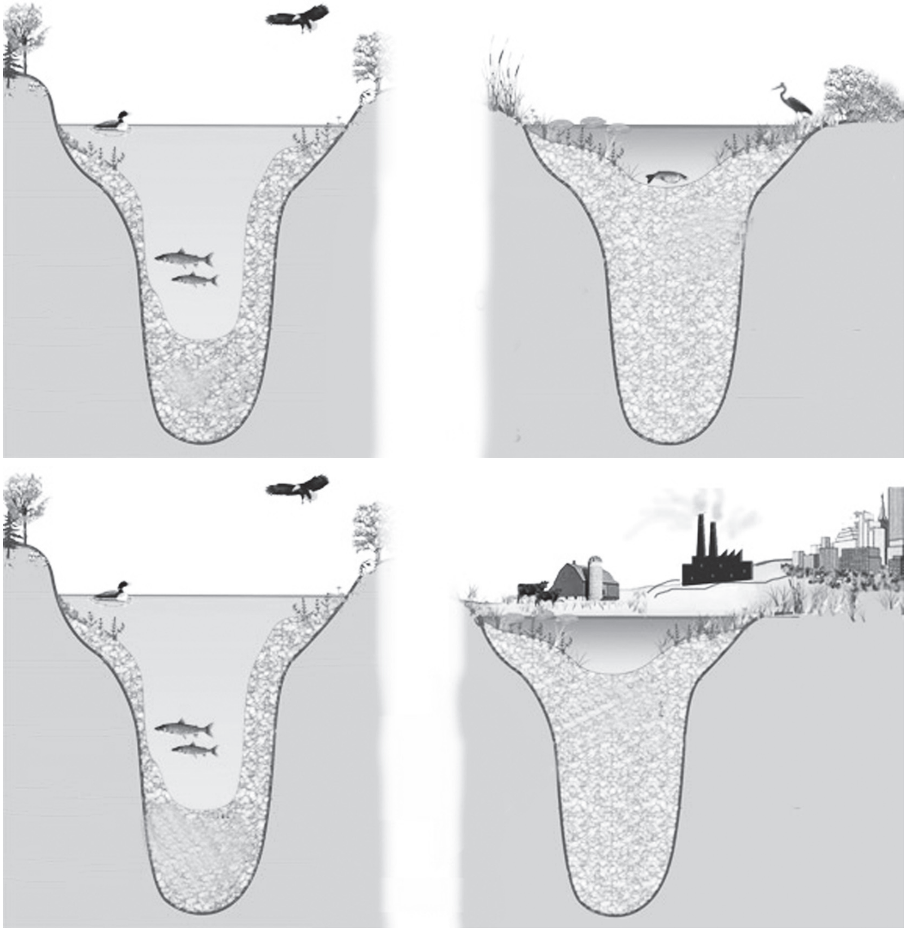
Source: *www.lakeaccess.org*

Figure 7.2 *The depth of the lake and its relationship with the ecology*
Cultural eutrophication is caused by water drained from
1. *agricultural and livestock raising areas*
2. *industrial areas*
3. *urban areas*
4. *residential areas*

Both cultural and ecological factors affect the population of plants and aquatic animals that are part of the food chain or food web and trophic status that can be divided into three phases.

1. Oligotrophic – The water is clear and there is not much algae but there is enough food for small fish. It is suitable for recreation.
2. Mesotrophic – There is more sediment and algae. The biodiversity is rich and in abundant but faces problems of low oxygen during the summer.
3. Eutrophic – Aquatic plants grow very quickly and eutrophication (having too many nutrients) takes place, resulting in polluted water and more sediment, making the lake shallow.

During the rapid growth of aquatic plants, there are a lot of nutrients that promote the biomass of plants and aquatic animals. The lake is usually crowded with algae and fish. This may result in less oxygen so a lot of aquatic animals may die in certain seasons.



Source: *www.lakeaccess.org*

Figure 7.3 *The natural development stages of the lake to eutrophication (above) take centuries but man-made development stages (below) take decades.*

7.5 Types of water source

The objectives of developing water sources are as follows:

1. Irrigation. The water is from earth surface (collected in reservoirs), rivers and streams, underground water (collected in wells) and treated wastewater whose BOD is less than 20 milligrams/liter

2. Consumption. The quality is the same as tap water.

3. Others. The quality is the same as the water for irrigation.

Source: *Mahidol News. A discussion forum to solve the crisis of Borapet Lake that has been dry for a long time by ASTV Puchatkarnonline August, 15, 2014.*

Figure 7.4 *Borapet, a fresh-water lake, has been affected by urban development projects and flood solution projects. These projects have been carried out without taking the ecology of the lake into consideration. Coupled with this, the lake's natural development resulting in more sediment and the reduction in size and depth of the lake. Above "In 2013, the water was drained from the lake to dredge the bed and make Monkey's Cheeks to solve flood problems. Since then, a continuous decrease in the level of water in the lake. Although more water is fed to the lake during the rainy season, the situation has not improved because villagers dig canals to take water out of the lake for their rice fields. The low level of water in the lake affects fishes, plants and people living around the lake"*

7.6 Steps of water source development in a large scale project and for irrigation

The steps of water source development in a large scale landscape project involve planning, data preparation, and projection that will lead to the success of the project. It can be concluded that the steps are as follows:

1. Studying of landforms and water channels around the project

Based on a 1 : 50,000 map displaying the project, the watershed, landform, quantity and location of natural water sources should be studied before options are considered. After that, a field study is carried out to locate the positions of dams, check dams or reservoirs.

2. Assessing the quantity and the quality of water
3. Hydrological calculations–total annual average quantity of rain, peak of floods to determine drainage
4. Studying bearing capacity and infiltration
5. Assessing construction costs and the design to see whether it is worth the investment

Dams

Dams are built to obstruct water that flows through valleys/hills so the water above the dam is kept in the valley. This area is called a reservoir. Damage to flooded areas has to be assessed before constructing the dam and the use of land near the dam has to be related to the watershed so that there is enough water for use. The dam should not be very big because it will cost a lot in constructing the spillway and a lot of sediment will accumulate. The bearing capacity at the bed of the dam has to be tested. The soil should be compact enough and able to hold water. The dam should be on high ground so water can be discharged without the help of a water pump.

Weirs

These are built to obstruct the flow of water and the water can flow over the ridge of the weir so that it can feed surrounding canals and ditches or provide surrounding areas with water. Weirs can be seasonal weirs made of sticks to prevent floods, semi-permanent weirs made of wooden posts and rocks, permanent weirs made of rocks, gabion boxes or reinforced cement, check weirs or check dams and Karen weirs.

One of the Royal Initiative Projects to restore run-down forest uses the Karen weir made of natural materials such as timber or bamboo trunks reinforced by rocks or bags filled with earth. The size of this weir depends on the width of the river or the community's requirements. Indigenous knowledge is applied to constructing this type of weir. Besides water, sediment is collected in this weir, and both can help restore the forest area.

The amount of water has to be assessed to see whether there will be enough water in time of need and enough to feed canals and ditches. The water flow should be straight to prevent erosion and the base soil should be hard enough to prevent water from escaping through holes in the bed. The weir should be constructed in the dry season.

7.7 Underground water

To keep underground water for consumption, metal casing is put in the ground to prevent the collapse of surrounding soil, rocks or sand. The diameter of 20-foot-long casing is 4-24 inches. The diameter of the casing depends on the maximum amount of water drawn. For example, 4 inches casing can allow 30 gallons of water to be drawn in one minute while for 16-inch casing the amount is 3,000 gallons/minute.

The casing can be a line pipe, standard pipe or a zinc coated metal pipe that does not last long. A screen is a pipe that stays at underground water

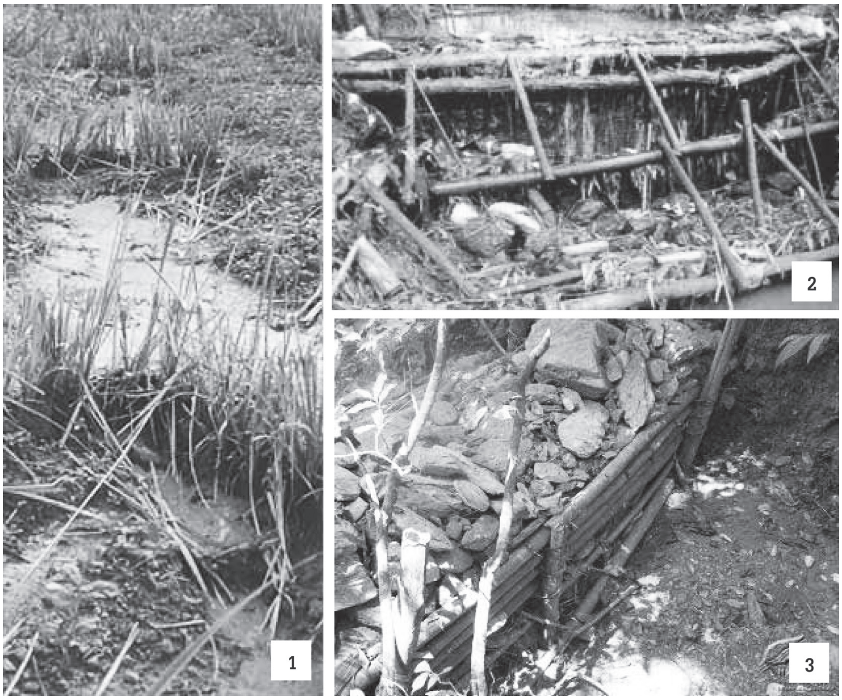


Figure 7.5 *Plantation of Vetiver grass to trap sediment and slow topsoil erosion [1], a Karen weir, a temporary weir to retard the velocity of water, construction projects [2], [3]*

level. If the underground water is near a saline water source, something should be done to protect the underground water.

The screen can be red brass, stainless steel or everdur metal. Gravel packing has to be done in the space between the screen and the earth wall.

An open hole does not require casing because the wall is composed of rocks that cannot collapse.

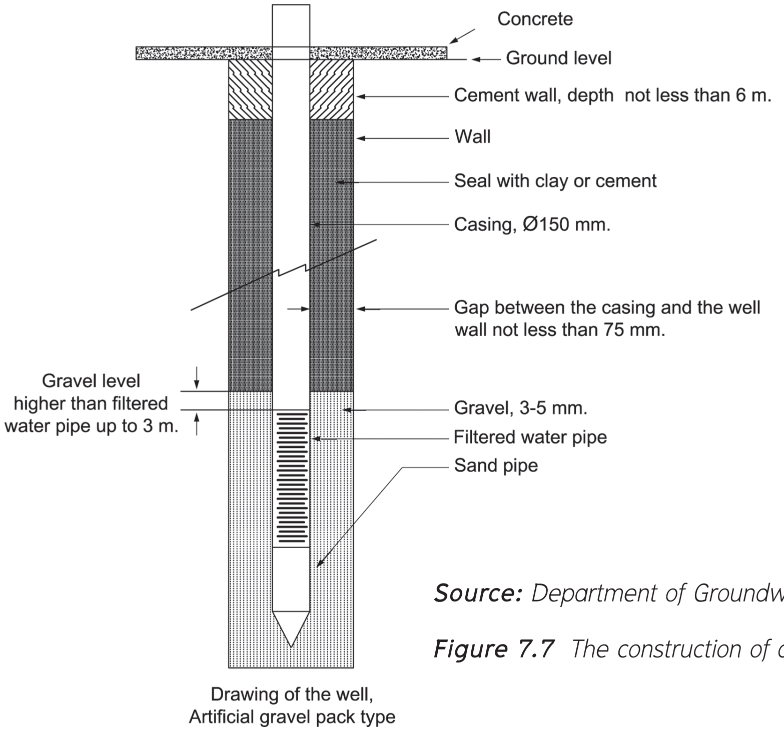
Well development

The objective is to prevent sand from entering the well and to lengthen the lifespan of the well. This development can be done by:

1. Bailing – drawing the water at the bottom to collect fine sand from the bottom

Figure 7.6 *The treated wastewater is drained to the artificial ponds in the Beijing Olympics Park*

2. Surging – using a plunger/swab to draw the water very quickly
3. Pumping – placing a suction pipe in the middle of the well and pumping the water up until the water is clear
4. Airlift – using an airlift pump connected with the drop pipe so that the air and water can wash the sand out. It is suitable to use this method during the first stage of the development. The sand has to be dug up.
5. Backwashed – another kind of airlift but the sand does not have to be dug up
6. Jetting – washing sand with high pressure water



Source: Department of Groundwater Resources

Figure 7.7 *The construction of a well*

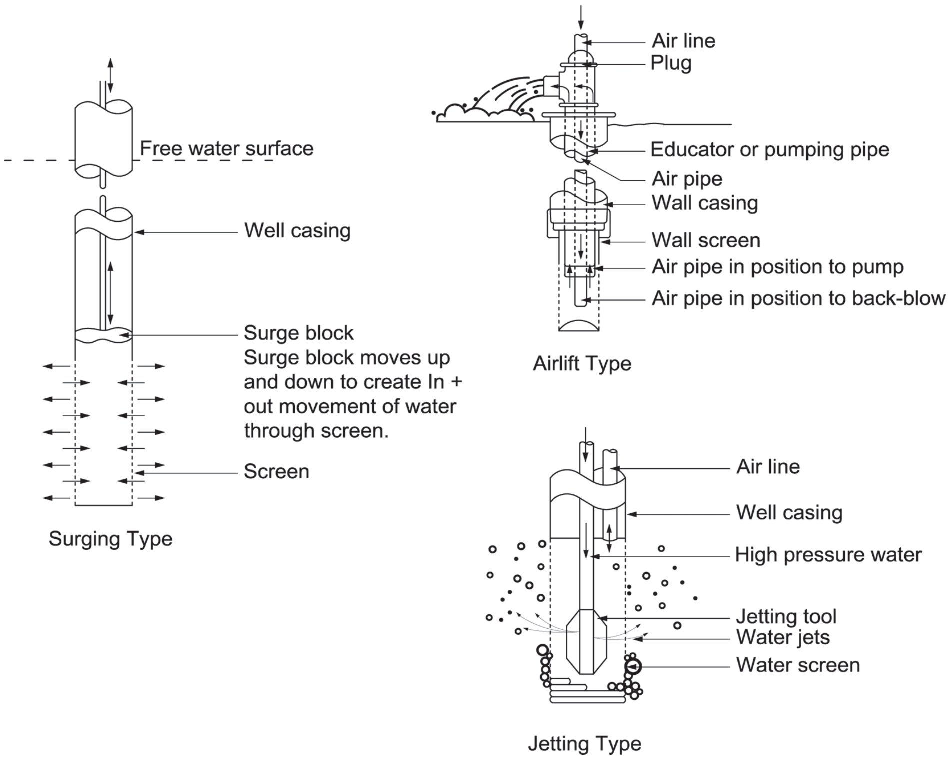


Figure 7.8 *Examples of well development through surging, airlift and jetting*

Chapter 8

Man-made Ponds, Pools, Fountains, Waterfalls

8.1 Preface

The technological development of man-made ponds, pools, fountains and waterfalls has made great progress during the past 30 years beginning from the dancing fountains employed in the Epcot Center Amusement Park in the Disneyworld, Florida, U.S.A. Artists then went on to design different fountain heads to meet their market demands. Spa shops and resorts for health have replaced chlorine with new methods of water treatment for ponds and more natural pond designs have been introduced. This chapter deals with forms and new technologies for creating fountains, waterfalls and artificial ponds.

8.2 Types of man-made ponds

At present, there are many types of man-made ponds such as swimming pools, hydrotherapy jacuzzi with bubbling system, wading pond, fountain pool, fish ponds, decorative ponds and natural swimming pools/ponds. Ponds are classified according to either function or construction. As regards function, ponds can be divided into public ponds, swimming pools in homes, swimming pools in hotels or resorts and swimming pools for competition.Concerning construction, ponds can be divided into:

1. **Overflow** – The water runs from the pool to the grating/gutter around the pool and then to the surge tank before running to the filter tank and back to the pool. The size of the tank is at least 10% of the size of the swimming pool. The water level is the same as the edge of the pool. This pool looks more attractive than the skimmer pool.
2. **Skimmer** – The water runs from the pool to the skimmer to the filter tank before running back to the pool. The water level is 10-20 centimeters. lower than the edge of the pool. The skimmer costs less than the overflow pool.
3. **Preformed pools** – These come in different sizes and materials. They are not popular choices for public pools or large pools.
4. **Sand bottom pools** – The bed of these are like that of a wok and a vacuum host cannot be used. The cleaning is done by flushing the dirt to the overflow and then to the surge tank.

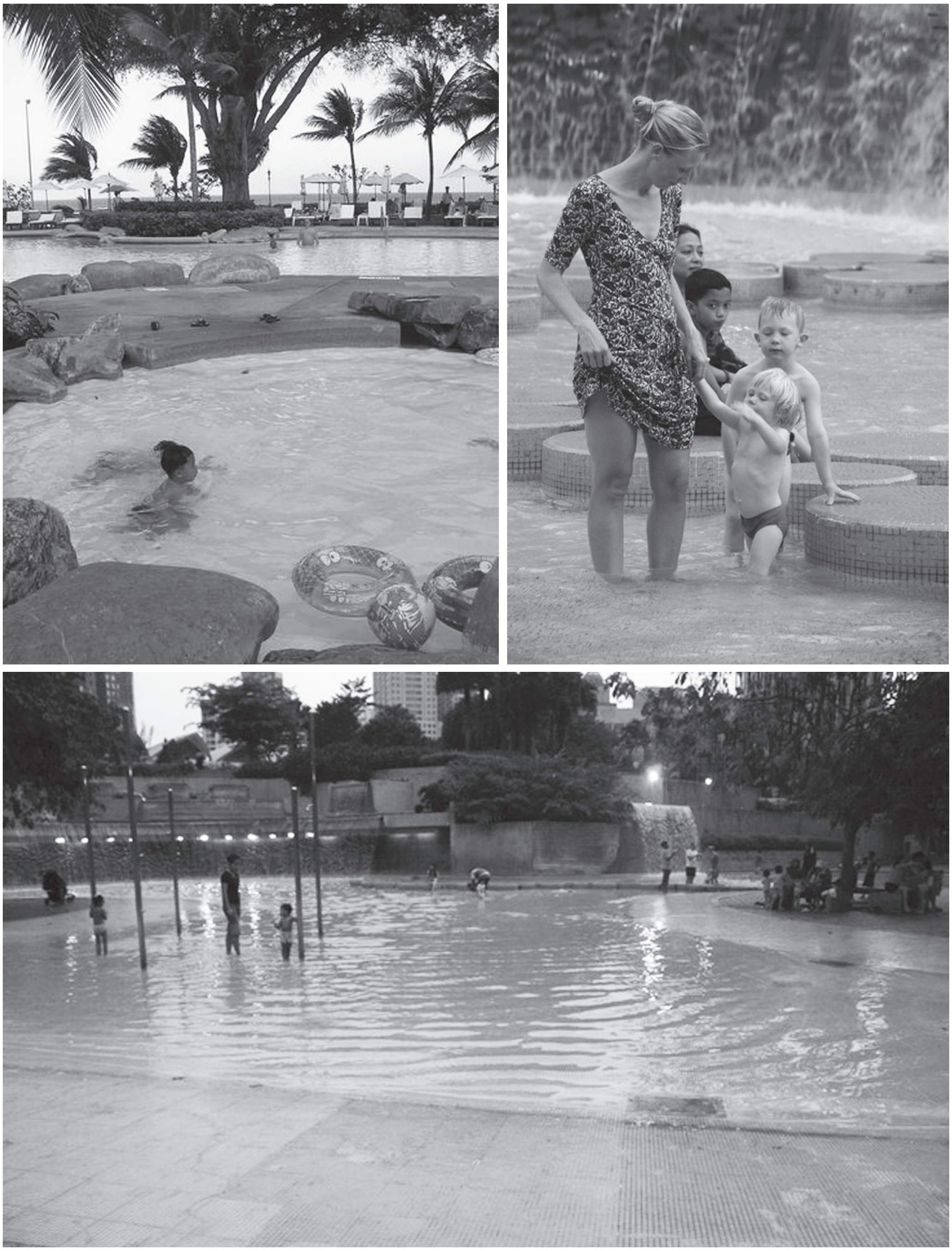


Figure 8.1 *Types of swimming pools Above left: A skimmer swimming pool whose edges are decorated with rocks to give it a more natural look Above right – below: A wading pool with play things for children provided free of charge in the KLCC Public Park, Kuala Lumpur*

Table comparing skimmer pool and overflow pool

List	**Skimmer**	**Overflow**
1. Budget	less	more
2. Difficulty of system Installment	less	more
3. Design	easy	expert consulation require
4. Attractiveness	water circulating in the pool and flowing to the surge tank under the pool	water over flow the edge of the pool into the surge tank and back to the pool
5. Total amount of water	less	more
6. Pool size	suitable for small pools	suitable for any pool
7. Construction duration	shorter	longer
8. 8. Maintenance	takes longer time to treat water	takes shorter time to treat water and more thorough

Factors to be taken into consideration when designing a pool

Safety – This is the most important issue. Landscape architects have to follow the related laws in terms of materials, installation of accessories, size and depth of pool and maintenance.

Materials – A suitable material texture that is not slippery when wet and a suitable color is also important because it enables the user to estimate the depth of the pool correctly.

Lighting – There should be enough lighting to enhance safety and the wiring has to be standardized.

Structure –This has to be suitable for the pool size and the area to prevent leakage. If the pool is in a building, accurate calculation for weight bearing has to be done.

Size – This has to be standardized and serve the purpose.

Function – At present, the swimming pool is not only for swimming, relaxing or competition but also use an dining area in some hotels.

Atmosphere – A variety of items related to atmosphere should be provided – private corners, shaded areas, sunny areas, etc. Plants and other vegetation can create a cozy atmosphere; however, proper maintenance is required.

Peripheral devices/furniture – These include sliders, fountains, waterfalls, shades, chairs and showers. Their locations are also important. For example, near a pool for children, there should be chairs for parents to sit so they can watch their children while swimming in the pool.

Budget/maintenance – The budget includes the costs of construction and maintenance especially for treating water and the quantity of circulating water.

The filtration system and the wastewater treatment system are key to the swimming pool and these systems differ from those of ponds. In general, there are three filtration systems for swimming pools.

1. **Sand filters**. These can filter particles of 25 microns and, currently, a compound of alumino silicate zeolite is replacing sand because it can filter particles of less than 25 microns.
2. **D.E. filters**. This is equipped with cloth so it can filter particles of 3-5 microns.
3. **Cartridge filters**. Three to fourlayers of cloth are used as cartridge so it can filter particles of 5-10 microns, but it is not popular.

There are six wastewater treatment systems for swimming pools but only three of them are popular.

1. **Chlorine**. In the forms of liquid, powder and bar, chlorine is used to eliminate germs in water whose pH is between 7.2-7.8. Hydrochloric acid is added to alkaline water and soda ash is added to acidic water for balance. The chlorine system is either automatic or manual which makes it difficult to control the amount of chlorine in the water and, in general, pools using manual system contain too much chlorine.

2. **Natural salt**. The salt chlorinator puts the salt through electrolytic process to turn it into liquid chlorine or sodium hypochlorite and hydrogen that can kill germs – bacteria, viruses and molds. The water is clear, clean and free of chlorine,which irritates the skin and eyes. With this system, the water also moisturizes the skin. This system is an automatic system.

3. **Ozone**. This is very effective at destroying germs. Ozone is caused when electrons react to oxygen.

4. **Bromine**. This is usually used with the chlorine system. Bromine along with chlorine is ejected into the pool. Bromine is used because it is more stable than chlorine and in appropriate amounts does not irritate the skin. A regular water test is needed to control the amount of bromine and chlorine.

5. **UV sterile**. Ultraviolet rays can destroy germs in 1-2 seconds and are usually used with another system.

6. **Copper ionization & electronic oxidation**. The dissolved electric charges can kill germs, inhibit the growth of algae and not irritate the skin or eyes.

Chemicals are used in maintaining the pool. For example, soda ash is used to treat acidic water and dry hydrochloric acid is used to treat alkaline water as well as chemicals to control algae, sedimentation accelerators, and chemicals to make water clear.

Figure 8.2 (above) A skimmer swimming pool whose water level is below the pool edges. This is the original system used in an old swimming pool called The Serpentine.

Figure 8.3 (right) A natural pool in the Serpentine Club. Part of the pond in the public park is used as a swimming pool.

Figure 8.4 A skimmer swimming pool that is naturally decorated. This is a swimming pool in a house.

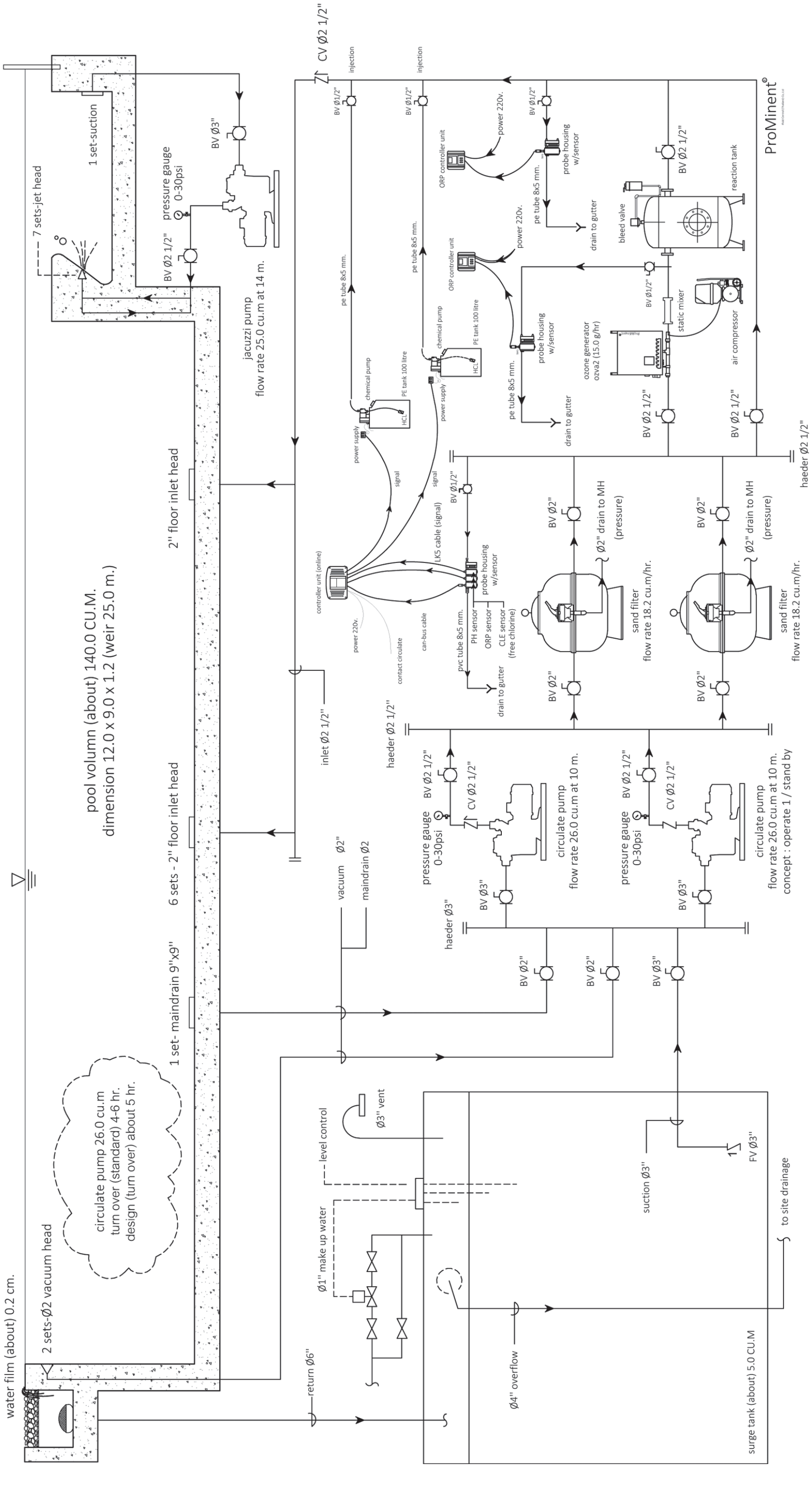


Figure 8.5 A construction plan showing the connections of the systems of a pool, devices of swimming pool systems and a whirlpool system composed of the chlorine control system. Ozone is used to treat water (the system is planned by ProMinent Fluid Controls (Thailand) Co, Ltd.).

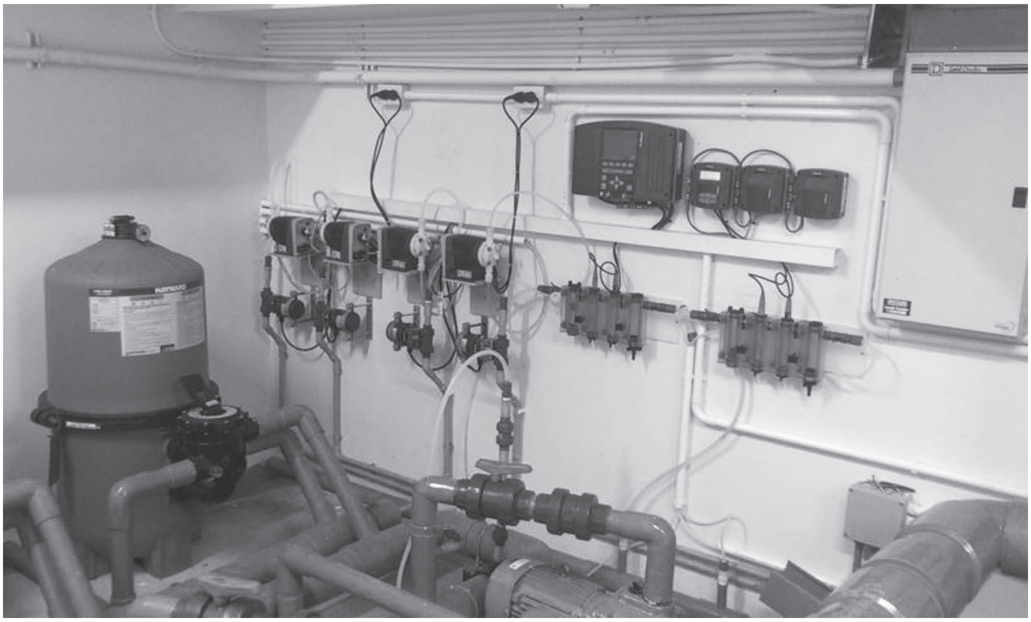


Figure 8.6 *The installation of swimming pool devices in the engine room. These are a filter tank, chlorine control system and ozone water treatment (the systems are planned by ProMinent Fluid Controls (Thailand) Co, Ltd.).*

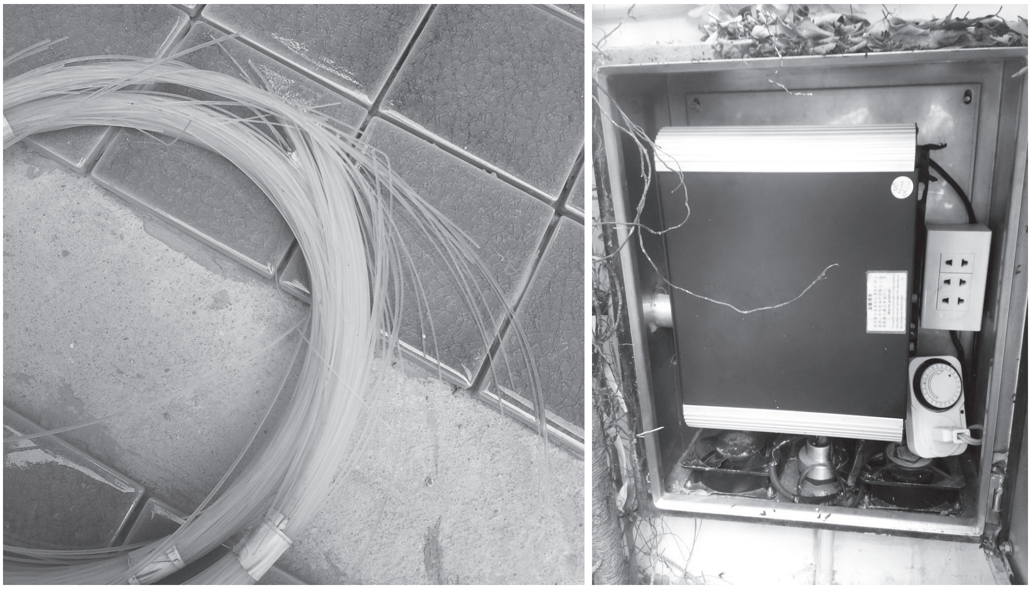
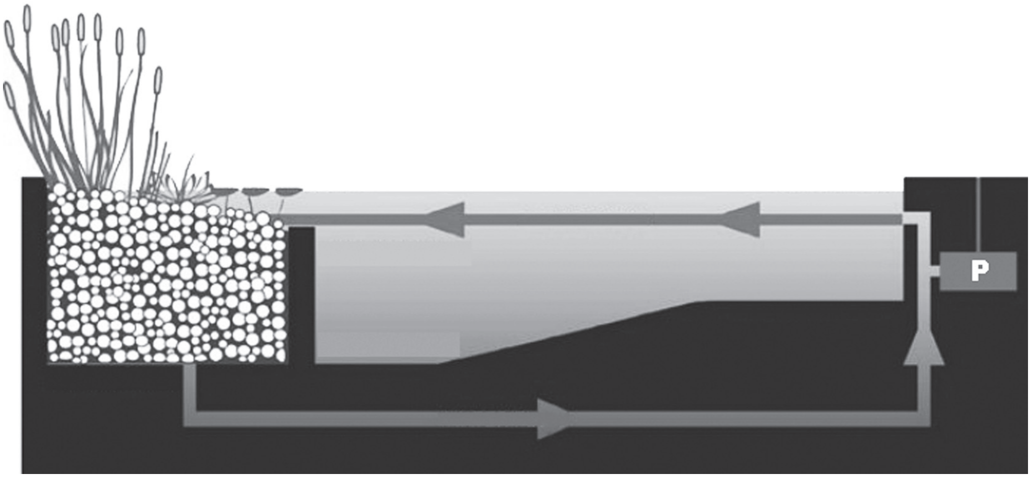


Figure 8.7 *Fiber optics for lighting in the swimming pool, flickering (left) and the control box and timer (right)*



Source: *Gartenart Swimming Ponds*

Figure 8.8 *Cross section of a natural pool*

Natural swimming ponds/pools

Nowadays, a natural swimming pond is popular because it is like swimming in a real natural pond. The water is treated naturally with the help of a man-made system that is designed to blend in well with the surroundings. This pond is equipped with a bio-technology used to filter and treat wastewater and designed to blend in with the environment but it is not recommended for large ponds.

8.3 Fish ponds/decorative ponds

Landscape architects have to design fish ponds and decorative ponds as well. Fish ponds can be as follows:

1. **Skimmer/waterfall external pond filtration**. This is suitable for a medium-sized and a large pond where fish are raised. Most of the budget goes into the filtration system and a pump. Installation and the maintenance are easy, but the systems have to be disguised well. The budget ranges from medium to rather high.

2. **Submersible pond filtration**. This is suitable for small and medium-sized ponds where no fish or a few fish one raised. The filtration systems and pumps available on the market are used. Maintenance is considered average depending on the position of the filter. One advantage of this system is that it is underwater and a structure to hide it is not required. The construction budget is cheaper than other systems.

3. **External pond filtration**. This is suitable for any pond where fish are not raised. The cost of construction depends on the size of the pond. The filtration system needs a structure to cover it but the maintenance is easy. This is suitable for a large pond with an irregular shape because the system can be placed anywhere in the pool. It is usually found in hotels and resorts.

8.4 Fountain pools

The fountain pools is composed of a pool, a water pump, an air pump, a filter, a drain overflow, a water distributor system, a fountain/waterfall nozzle, a controlling system, an electrical system (for the pump, lighting, controller). The factors to be considered are the same as those for a swimming plus a further five important factors.

Quantity and quality of water – The size of the fountain head varies according to the quantity of water. The filtration system may not be needed for the fountain pool so good quality water ensures the long life of the fountain head.

Location and wind direction – A fountain nozzle that discharges water high into the air is not suitable out in the open and windy areas. In general, the width of the pool has to be in line with the height of the fountain so that the water will not splash out of the pond. Landscape architects have to choose the right fountain head for the site to make sure that the fountain does not make so much noise or discharge too much water.

In addition, the site owner should be informed of the operational cost of the fountain. Sometimes the installed fountain is not in use because its operational cost is high and the owner did not set aside the budget for this.

Steps of designing a fountain

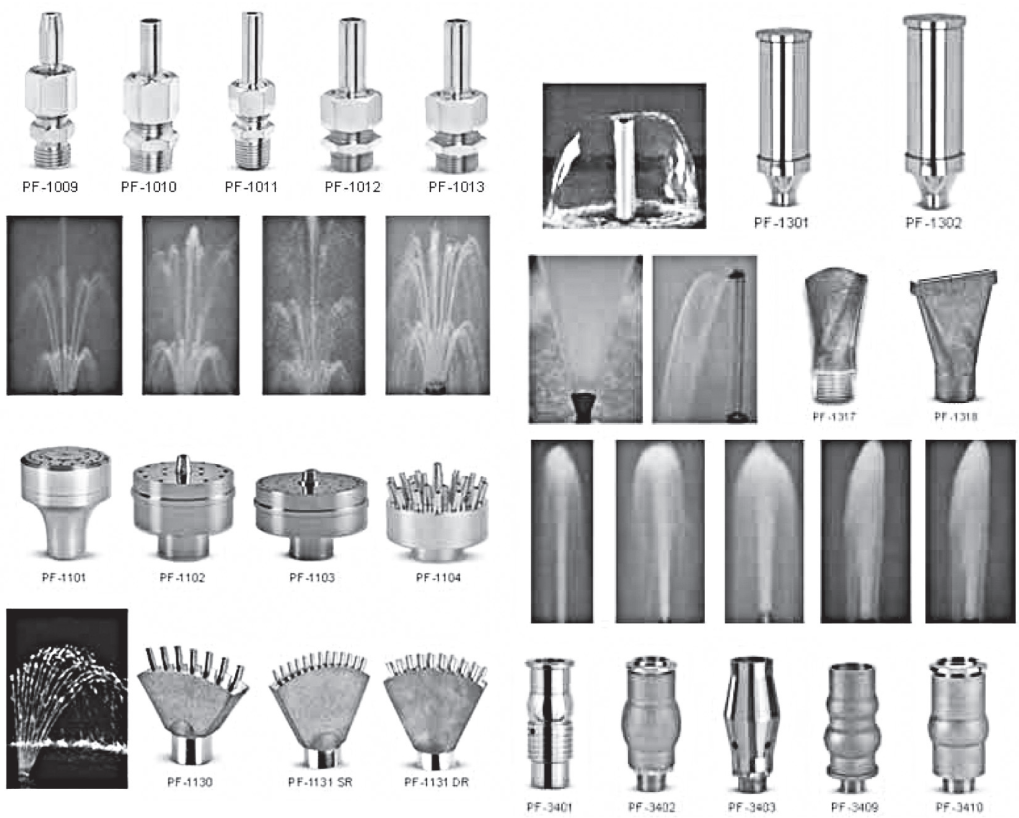
1. Specify the effects or characteristics of the fountain.
2. Specify the nozzle, number, size and position.
3. Specify the size, form and depth of the pool according to the wind direction and the fountain.
4. Specify the size of the water pump and piping system.
5. Choose the filtration system.
6. Decide where to put the filtration system and the pumping system.
7. Specify the lighting system.
8. Specify the control system.
9. Decide where to put the switch of the control system in line with the fountain system.

Types of fountain nozzle

The fountain nozzle can convey the architect's ideas. In the past, there were not many types of fountain nozzle to choose from so the design of the pool was the design of its components, but today there are many types and the technology to control the discharge of water has advanced, leading to more attractive designs of fountain pools. The following are types of fountain nozzle.

1. Adjustable clear stream single jet nozzles
2. Vulcan fix jets/multi jet nozzles
3. Finger jet/multi jet nozzles
4. Bell/water film nozzles
5. Fan jet/water film nozzles
6. Tulip jet
7. Water castle jets
8. Foam nozzles/foam effect nozzles
9. Dandelion (sphere)/sphere effect nozzles
10. Rain curtain
11. Fog curtain
12. Jumping water

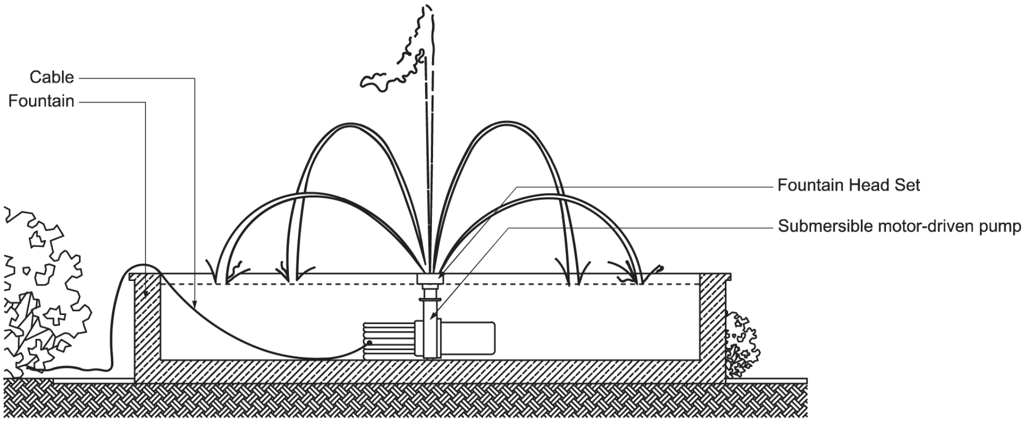
Moreover, each nozzle can discharge water differently such as bore jets, aerator jets, foam jets or V-jet film nozzles. The installation of the nozzle is complicated so the architect has to be thorough about this, but a computer program can control the operation of the fountain nowadays.

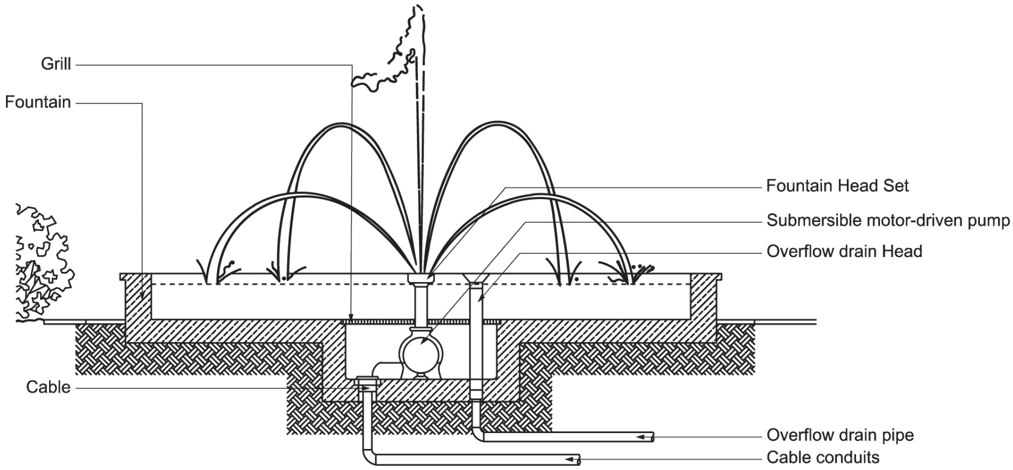


Source: *Catalog of Acuascape fountain nozzles*

Figure 8.9 *Fountain nozzles that can display different effects such as a fan, fingers, a bunch and a bell.*

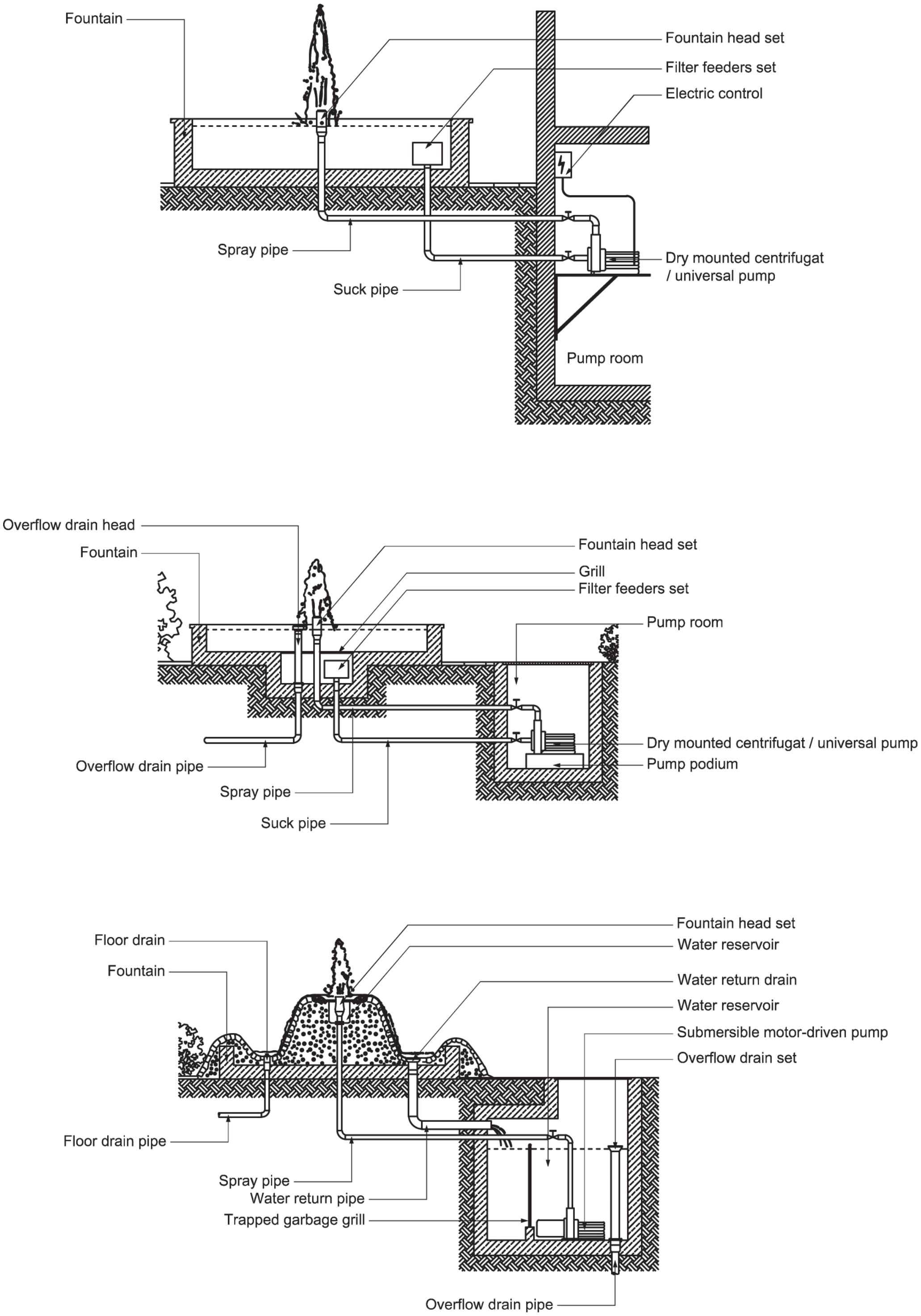
Figure 8.10 *A waterfall that is designed to have a whirlpool outside and the waterfall inside at the Suntec Department Store in Singapore*





Source: *Handbook for Installing Oase Living Fountain*

Figure 8.11 *Installation of fountain nozzles and water circulation systems ranging from the least complicated to most complicated (opposite)*



Fountain
Fountain head set
Filter feeders set
Electric control
Spray pipe
Suck pipe
Dry mounted centrifugat / universal pump
Pump room
Overflow drain head
Fountain
Fountain head set
Grill
Filter feeders set
Pump room
Dry mounted centrifugat / universal pump
Pump podium
Overflow drain pipe
Spray pipe
Suck pipe
Floor drain
Fountain
Fountain head set
Water reservoir
Water return drain
Water reservoir
Submersible motor-driven pump
Overflow drain set
Floor drain pipe
Spray pipe
Water return pipe
Trapped garbage grill
Overflow drain pipe

Figure 8.11

Figure 8.12 *Effects of fountain nozzles making water go in different directions such as bore jets-water splashing film-like or knot-like*

Figure 8.13 *Fountain pools can be designed to have many effects such as the Buckingham Fountain, a fountain decorated with lights in Chicago, different kinds of fountains in Alnwick Castle Garden in Scotland and the fountains in the Royal Flora Expo in Chiangmai Province.*

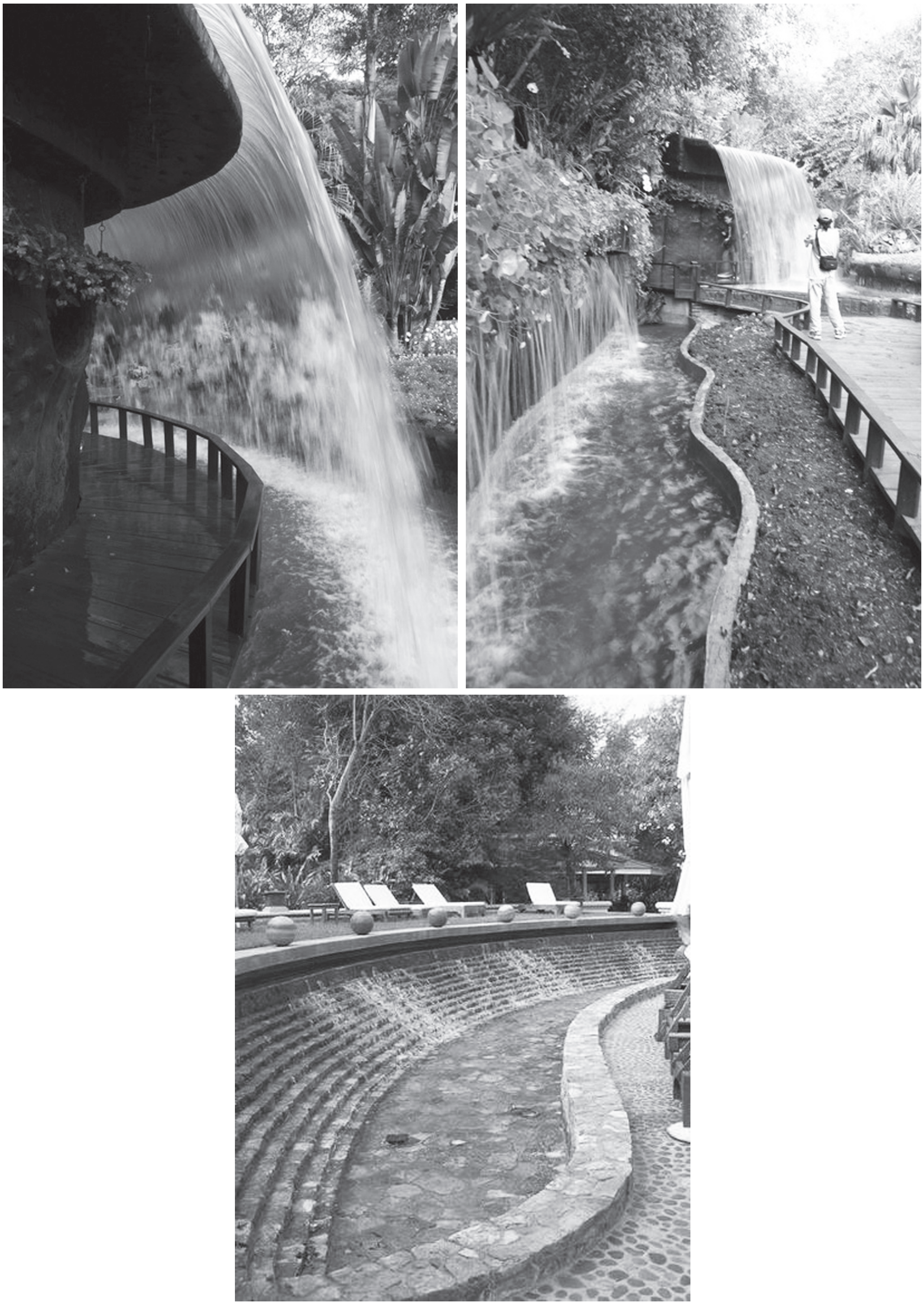


Figure 8.14 *A waterfall*

Figure 8.15 *The fountain and the sculptures in Mustang Plaza in Las Colinas, Texas, U.S.A. designed by Halprin, a landscape architect*

Figure 8.16 *The Crown fountain in Millenium Public Park, Chicago. It is equipped with an LCD screen and timer.*

Figure 8.17 *The Diana Memorial. The computer program controls different kinds of nozzles discharging water differently to represent the princess's way of life. The fountain was designed by Gustafson.*

Figure 8.18 *A musical fountain. The curtain fountain is the screen for the movie.*

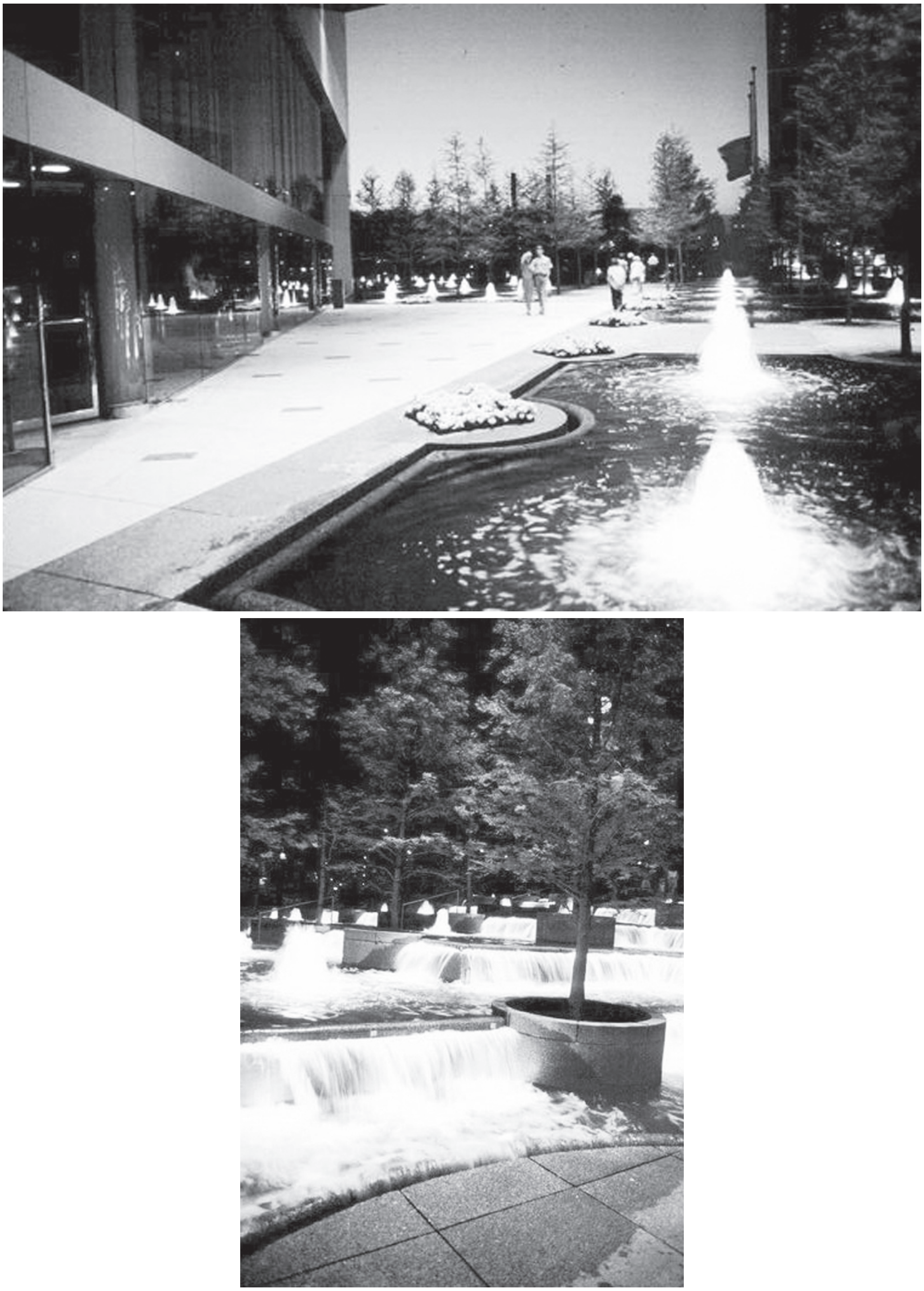


Figure 8.19 *A fountain decorated with lights at the first floor of an office in Dallas, Texas, U.S.A. designed by Halprin*

A pond for collecting wastewater from the project before going to a facultative pond. The water is black or dark grey and smelly. Its BOD is likely to be over 20 milligrams/liter.

Chapter 9

Wastewater and Treatment

9.1 Preface

Natural resources can be divided into three major groups: non-renewables (fossil fuels, natural gas and minerals), renewables that cannot be restored in nature both in the short - and long-term (forests, animals, plants, soil and water) and endless (sunlight, air). Water in the water cycle is considered a circulating natural resource, but it can be depleted by man. Wastewater has been contaminated at different levels so before treating wastewater, an insight into the types of wastewater needs to be gained so that proper treatment can be assigned.

Landscape architecture deals with planning the land use and resource management of the site. Water is an important resource that landscape architects have to consider so that a proper system is applied to manage water.

9.2 Definitions and types of wastewater

Wastewater refers to contaminated water that cannot be reused and if discharged into natural water sources, will pollute the water there. Base on its origin, wastewater can be classified into domestic wastewater, factory wastewater and agricultural wastewater.

Domestic wastewater is closely related to landscape architectural designs. Residents' daily activities lead to domestic wastewater.

9.3 Assessment of wastewater ratio

The amount of wastewater discharged from households and buildings accounts for 80% of the amount of water used or it can be assessed from the population or building areas as shown in the table below.

Table : Ratio of wastewater discharged (liter/person - day)						
Region	1992	1997	2002	2007	2012	2017
Central Plains	160-214	165-242	170-288	176-342	183-406	189-482
North	183	200	225	252	282	316
Northest	200-253	216-263	239-277	264-291	291-306	318-322
South	171	195	204	226	249	275

Source: *Study Project to Prioritize Domestic Wastewater Management, the Office of Natural Resources and Environmental Policy and Planning, 1995*

Amount of wastewater from various types of buildings		
Building	Per unit	Liters/day
Condominuim/house	Unit	500
Hotel	room	1,000
Apartment	room	80
Service Site	room	400
Housing Estate	person	180
Hospital	bed	800
Restaurant	square meter	25
Market	square meter	70
Department store	square meter	5
Office	square meter	3

Amount of wastewater - residential zone		
Source	liters/person - day	
	normal	range criteria
Apartment/Condominium	normal	200-260
Housing		
- sverage	280	190-350
- good	310	250-400
- well-to-do	380	300-550
- vacation house	190	100-240

Amount of wastewater - commercial zone			
Source	Unit	liters/person - day	
		normal	range criteria
Airport	passenger	10	8-15
Service garage	car	40	30-50
	employee	50	35-60

Amount of wastewater - comertial zone			
Source	Unit	liters/person - day	
		normal	range criteria
Bar	client	8	5-20
	employee	50	40-60
Hotel	guest room	1,200	500-800
	employee	40	30-50
Amount of wastewater - comertial zone			
Source	Unit	liters/person - day	
		normal	range criteria
Factory (except production process/canteen)	employee	55	30-65
Laundry	machine	2,200	1,800-2,600
	washing	190	180-200
Office	employee	80	50-100
Restaurant	meal/person	10	8-15
Department store	bathroom	2,000	1,600-2,400
	employee	40	30-50
Shopping center	car	4	2-8
	employee	40	30-50

Source: *Issues about the amount and types of domestic wastewater in Thailand, Document for the 36 TEI meeting, Thailand Environment Institute Foundation 2536*

9.4 Wastewater properties

Wastewater properties determine the method of treatment. Biochemical Oxygen Demand (BOD), an index indicating wastewater, reveals that the water in rivers and canals in Bangkok is so polluted that it is not suitable for leisure activities. Color and smell can be comparable with BOD level as follows:

Color	BOD (milligram/liter)
Green or brown	less than 15
Black or grey	more than 20
Smell	
No smell or faint smell	less than 15
Foul smell	more than 20

9.5 Wastewater characteristics

Wastewater characteristics can be divided into physical characteristics, chemical characteristics and biological characteristics.

Physical characteristics are determined by the amount of solids and particles that can be classified as:

1. Total solids such as dissolved solids and suspended solids
2. Settleable solids

Biological characteristics are determined by an instrument checking the amount of coliform or total coliform (MPN/100 ml)

Chemical characteristics are determined by amount of grease, pH, BOD, Chemical Oxygen Demand (COD), total as N (such as organic nitrogen, free ammonia, nitrites, nitrate), total as P (such as organic phosphorus, inorganic phosphorus, chloride, sulfate) and alkalinity as $CaCO_3$.

9.6 Indicators of wastewater

In general, indicators or indexes of wastewater are:

1. Biochemical Oxygen Demand (BOD) – The amount of oxygen that microorganisms use in disintegrating organic matters and turning them into carbon dioxide and water

2. Chemical Oxygen Demand (COD) – The total amount of oxygen to be used in the oxidation of organic matters to become carbon dioxide and water

3. Suspended solids (SS) – Suspended small solids

4. Dissolved oxygen (DO) – Amount of oxygen dissolved in water

5. TKN – Amount of nitrogen in the form of ammonia nitrogen combined with organic nitrogen

6. Total phosphorus – Amount of phosphorus in water that is measured as total phosphorus

7. Fat oil and grease (FOG) – Amount of fat oil and grease in water

8. Mixed liquor suspended solids (MLSS) – Amount of microorganism sediments raised in an oxygenated pond to be used in dissolving organic matters in wastewater

9.7 Wastewater treatment

Wastewater is treated according to its characteristics: 1) physical treatment, 2) chemical treatment and 3) biological treatment.

1. **Physical treatment**: Separation of contaminants from wastewater. Such as large solids, paper, plastic, food matters, gravel, sand, fat and oil using grease trap, grit chamber, grease tank or sedimentation tank.

2. **Chemical treatment**: Using Chemical reactions to treat contaminants. This treatment is used to treat wastewater that has either a pH too high or too low, toxins, heavy metals, suspended solids that are hard to settle, water-soluble fat and oil, high amounts of nitrogen or phosphorus and germs. The chemical reactions are performed in the rapid mixing tank, flocculation tank, sedimentation tank, filtration tank or disinfection tank.

3. **Biological treatment**: Application of biological processes or microorganisms to get rid of contaminants especially organic carbon, nitrogen and phosphorus. These microorganisms feed on these contaminants and the microorganisms can be either aerobic or anaerobic organisms. Wastewater treatment systems that rely on biological processes are activated sludge (AS), rotating biological contactor (RBC), oxidation ditch (OD), aerated lagoon (AL), trickling filter, stabilization pond, upflow anaerobic sludge blanket (UASB) and anaerobic filter (AF).

9.8 Choosing treatment system and types of system

The wastewater treatment system varies according to the site, the project and the budget. It can be:

1. **Onsite treatment** that can be:
   - a grease trap
   - a septic tank
   - an anaerobic filter
   - mound filtering, trench filter
   - mound/trench filtering
2. **A stabilization pond** consists of
   - an anaerobic pond
   - a facultative pond
   - an aerobic pond

If there are many ponds connected to each other, the last pond is the maturation pond.

3. **An aerated lagoon** consists of
   - an aerated lagoon
   - a polishing pond
   - a chlorine contact tank

4. **Constructed wetland** consists of
   - free surface wetland (FSW)
   - a vegetated submerged bed (VSB)
5. **Activated sludge** consists of
   - an aeration tank
   - a sedimentation tank

6. **An oxidation ditch** is activated sludge that uses aerobic bacteria to dissolve organic matter. The ditch consists of:
   - a grit chamber
   - an equalizing tank
   - an oxidation aerated lagoon
   - a sedimentation tank
   - a rotating air lift pumping tank
   - a chlorine contact tank

Figure 9.1 *The area to collect and treat wastewater from the sources – toilets and washing area. The wastewater is carried through the pipe (left) to the area (right) to be treated.*

Figure 9.2 *A facultative pond and a man-made pond in the Asian Institute of Technology, which covers a large area and is located on the main road. Later they were replaced by a treatment plant so that the area could be used for other purposes.*

7. A rotating biological contactor (RBC) consists of:
   - a primary sedimentation tank
   - a rotating biological contactor
   - a sedimentation tank
   - a chlorine contact tank

8. Fixed film aeration uses many kinds of microorganisms cultured in the aerated lagoon, 95% of which are bacteria, followed by algae, fungi and protozoa. The system consists of:

- an airless maturation pond
- plastic media/biofilm aerated lagoon
- a sedimentation tank
- an air lift pump

9.9 Steps of wastewater treatment

The steps of wastewater treatment are as follows:

Preliminary treatment and primary treatment: to separate sand, gravel and large solids from wastewater through a coarse screen, fine screen, grit chamber, primary sedimentation tank and skimming devices. 50-70% of the suspended solids and 25-40% BOD of organic matter is removed.

Secondary treatment or biological treatment: to separate small suspended solids, soluble and non-soluble organic matters. Cultured microorganisms that disintegrate organic matter faster than natural microorganisms are used in this treatment. The waste water is then sent to the secondary sedimentation tank before leeing sent to the disinfection process. After that, the water is discharged to the natural water ways or is reused. More than 80% BOD of suspended solids and organic matters are removed.

Advance treatment or tertiary treatment: this is the process to eliminate nitrogen, phosphorus, color, suspended solids and others that have not been removed by secondary treatment. This should improve the quality of water enough so it can be recycled and also help deter the unusual growth in algae that causes pollution, cure the awful reflection of colors in water sources and other problem that secondary treatment could not. Phosphorus can be remove through a chemical or a biological process. Nitrogen can be removed through the chemical or biological process through two steps: nitrification and denitrification. Nitrification is the process that changes ammonia nitrate into nitrite. This process takes place in an oxygenated context and denitrification is a process that changes nitrite into nitrogen in a context without oxygen.

Biological treatment can remove both phosphorus and nitrogen through nitrification and denitrification. However, denitrification accompanied by phosphorus luxury uptake can be used to remove both elements.

Filtration is a physical treatment that removes suspended solids that are hard to settle.

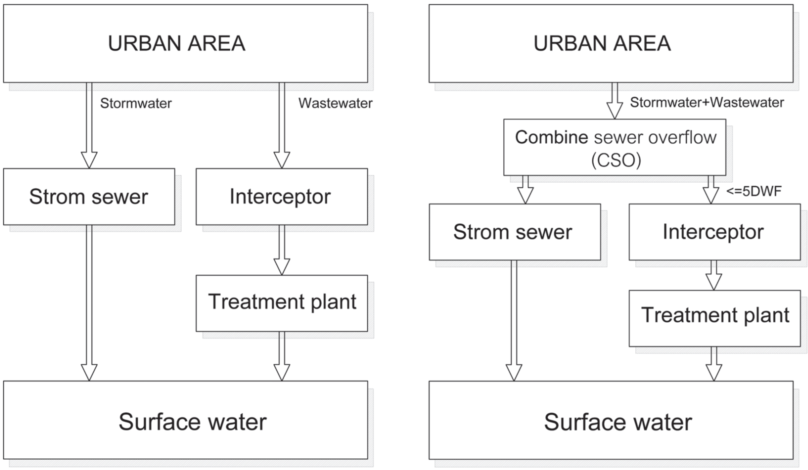
Adsorption is used to remove organic matters and foul smell.

9.10 Wastewater discharge system

Wastewater can be discharged by a separate sewer system and combined sewer system. The comparison of two the systems is shown below.

	Combined sewer system	**Separate sewer system**
Combined sewer overflow (CSO)	necessary	not necessary
Size of system	larger	smaller
Size of pump	larger	smaller
Self-cleansing	during rainfall	once a day
Fluctuation in quantity and intensity of wastewater	high	low
Sediment, stones and sand	much	little
During floods	Floods from waste water.	Floods from rain water.
Construction site	requires smaller area	requires large area
Cost	less expensive	more expensive

(Separate Sewer System) (Combine Sewer System)



Seperate System Combine System

9.11 Wastewater treatment sludge disposal

Sludge treatment can be done through

– thickener in which either sedimentation or floatation is applied.

– stabilization that uses oxygen or does not use oxygen to reduce the amount of organic matter to reduces the smell of sludge

– conditioning this makes the sludge suitable for further uses such as fertilize or for treatment of agricultural land.

– dewatering that is performed by a vacuum filter, filter press or centrifuge. After that, the sludge will be dried on the sludge drying bed before being buried, burned or used for other purposes.

Sludge is disposed of by:

– Landfill

– Composting to be used as a fertilizer since sludge is composed of plant nutrients such as nitrogen, phosphorus and other necessary minerals.

– Incineration. Over 40% of solids in the sludge that are almost dry is burned because it cannot be used as fertilizer or buried.

Figure 9.3 *A man-made wastewater treatment pond designed to be use as a public park in the Olympics Park Project in Beijing*

Figure 9.4 *A man-made pond using combined systems to treat wastewater in the Asian Institute of Technology. Some plants are used to treat wastewater before the water is discharged.*

Popup spray sprinkler head

Chapter 10

Landscape Irrigation Systems

10.1 Preface

Unlike architecture that deals with hardscape, landscape architecture deals with softscape such as vegetation, light and water. Landscape irrigation includes water systems and irrigation systems are vital aspects in this field. Landscape architects have to look for a water source that can provide enough water for the project. The water system and irrigation system have to be designed so that they can blend in with the landform, climate and vegetation in the project.

10.2 Irrigation systems

Irrigation systems can be divided according to purpose as follows:

Agricultural irrigation for garden crops, field crops, flowering plants and foliage

Landscape irrigation for residential areas, commercial zones, offices, public parks, sports grounds, hotels, schools and universities

Golf course irrigation

Drip irrigation: low-volume, water conserving Xerigation solutions

Interior landscape irrigation

10.3 Estimation of water needs

The need for water can be estimated based on the plants to be grown.

Types of plant	Maximum water needed/day		Average water needed/day
	ml./sq.m.	m^3./rai/day	m^3./rai/year
Lawn*	5-7	8.0-11.2	3,504
Fruit tree	3-5	4.8-8.0	2,336
Foliage	2-5	3.2-8.0	2,044

** Grass that can resist drought and native grass need less water than the above.*

The estimation of water needed in the project one has to take into consideration land use, activities and vegetation. At present, the focus is on conserving water sources and using water to the maximum so plants that require less water are preferable. Native plants, therefore, are highly recommended. The following is the estimation of water needed in a project.

A project that accommodates a resort and an 18 hole golf course covers an area of 1,200 rai.

The estimation of landscape irrigation: 400 rai golf course (70% of the area), 800 rai foliage area (10% of the area), 420 rai lawn and fruit trees, 100 rai ponds, 320 rai areas that do not require water.

Item	Unit	Total	Water needed/unit (sq.m./unit/day)	Total water needed per unit (sq.m./day)
Irrigation				
Golf course 400x0.7	rai	280	9.0	2,520
Foliage 800x0.1	rai	80	5.0	400
Lawn & fruit trees	rai	420	5.0	2,100
Ponds	rai	100	8.0	800
Other	rai	320	-	-
Total		1,200		5,820

10.4 Steps of designing irrigation systems

The design of a good watering system requires an understanding about devices used in the system such as sprinkler heads and other components. The sprinkler heads can be:

1. Fixed spray-type: nozzle
2. Rotor-type
3. Impact sprinkler
4. Rotary nozzle
5. Popup spray
6. Root watering
7. Valves: low volume, drip, Xerigation

Figure 10.1 *Popup spray sprinkler heads that will emerge when it is time to water the plants and submerge when the watering is done.*

The sprinkler parts are:

1. Pop-up style sprinklers
2. Shrub style sprinklers

The installation of valves and system connecting can be:

1. VIH (Valve-in-head)
2. VUH (Valve-under-head system)
3. In-line system, one control valve

Factors to be considered when choosing the sprinkler are the radius, pressure (the unit is bar or psi) and flow rate (the unit is square meters/hour or liters/second). The distribution of water can be full circle (F), half circle (H), quarter (Q) and tri-quarter circle (TQ).

Source: *http://ralnbird.com*

Figure 10.2 *Different types of nozzle*

The following are the steps in designing the watering system.

1. Collecting data: project plan and tap water system. In Thailand, tap water is measured in the metric system: gallons per minute (GPM) but in foreign countries such as the United States, the measuring system is pounds per square inch (PSI).
2. Choosing devices
3. Locating devices
4. Drawing hydro-zones and valve zones
5. Specifying the sizes of pipe by taking the following into consideration:
    5.1 Types of soil
    5.2 Soil texture and infiltration
    5.3 Wind which affects the effective radius of sprinkler
    5.4 Avoid water pressure problems by not using one valve for many types of head

The space between sprinklers should be equal to the watering radius between the sprinklers or no lees than 60%, which would leave 40% of overlapping areas. This would result in high wateing efficiency.

The sprinkler heads can be positioned in:

1. Triangular spacing
2. Square spacing
3. Single row spacing
   - Single row-one speed spacing
   - Single row-double speed spacing
4. Double row spacing

Piping should be done much a way that it is economical, easy to manage and taking into account the actual condition of the site. The piping can be a split supply line, loop circuit, 2 circuit/area, individual sprinkler control and collar sprinkler. However, the piping in a golf course needs to be more specific since landscape architects have to decide which watering system is suitable for the green and freeway as follows.

1. Single big head for the whole green is more economical but the texture of the grass maybe uneven.
2. Three heads per green can cover more area.
3. Four heads per green
4. More than four heads per green

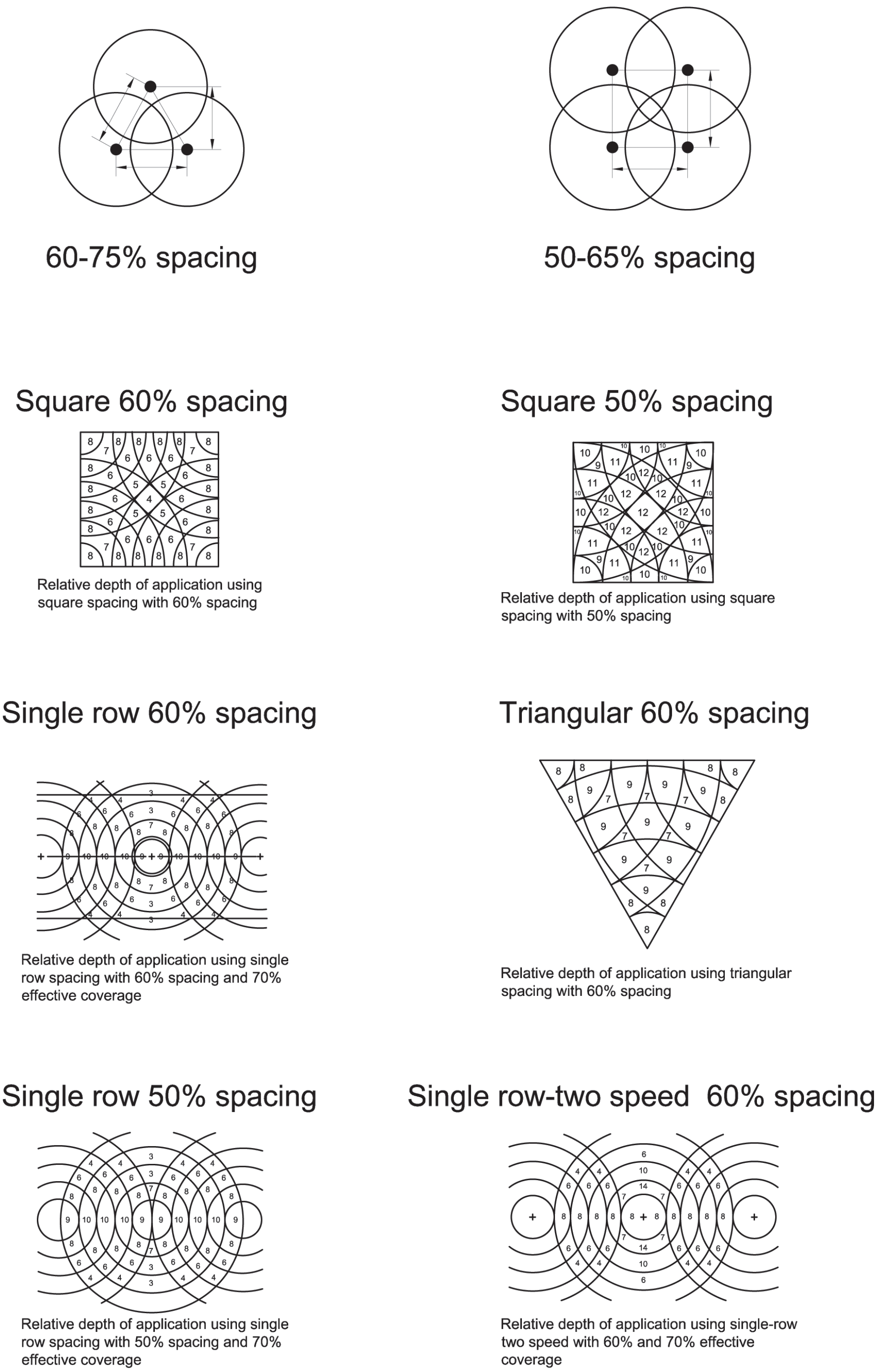


Figure 10.3 *Layout of sprinkler heads*

10.5 An example in designing an irrigation system

(Source : http://www.rainbird.com)

Step 1. Study the project area

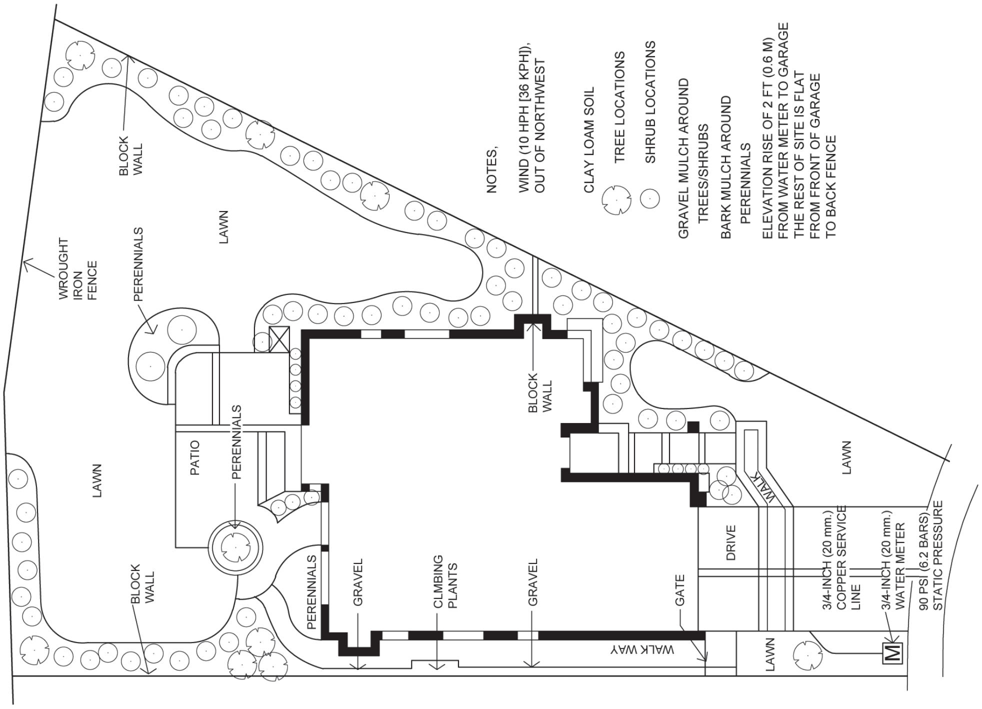
Step 2. Study details about planting design, wind directions, soil characteristics and contours

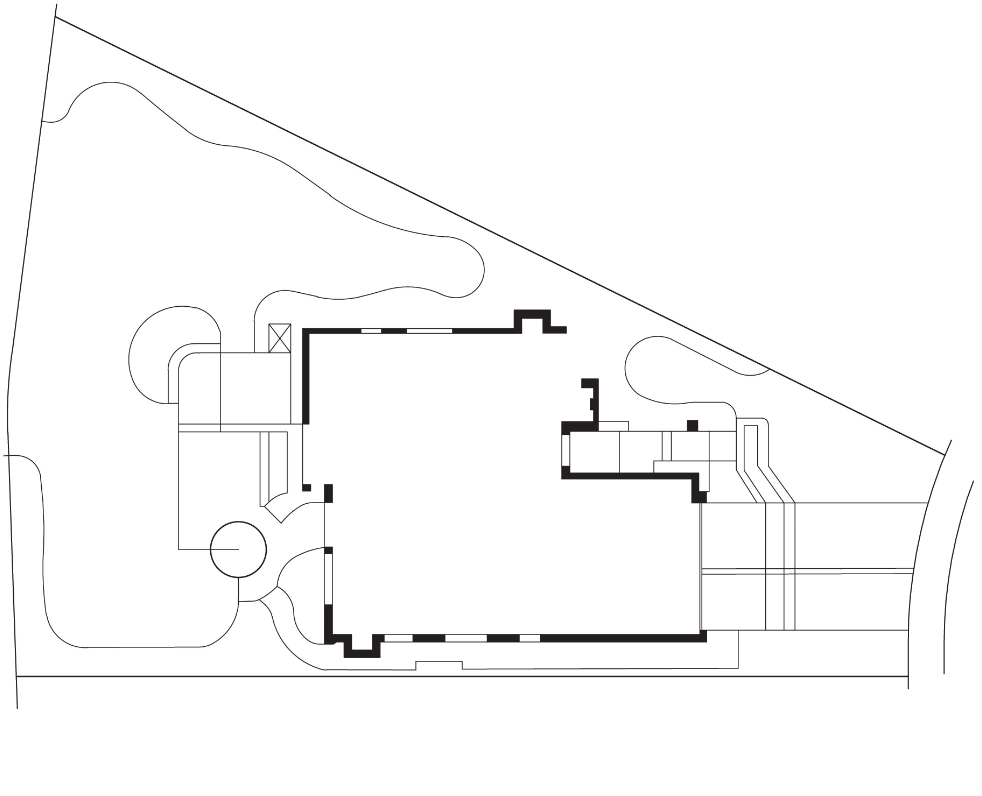
Step 3. Specify the locations of sprinkler heads with suitable spacing in relation to vegetation and concepts

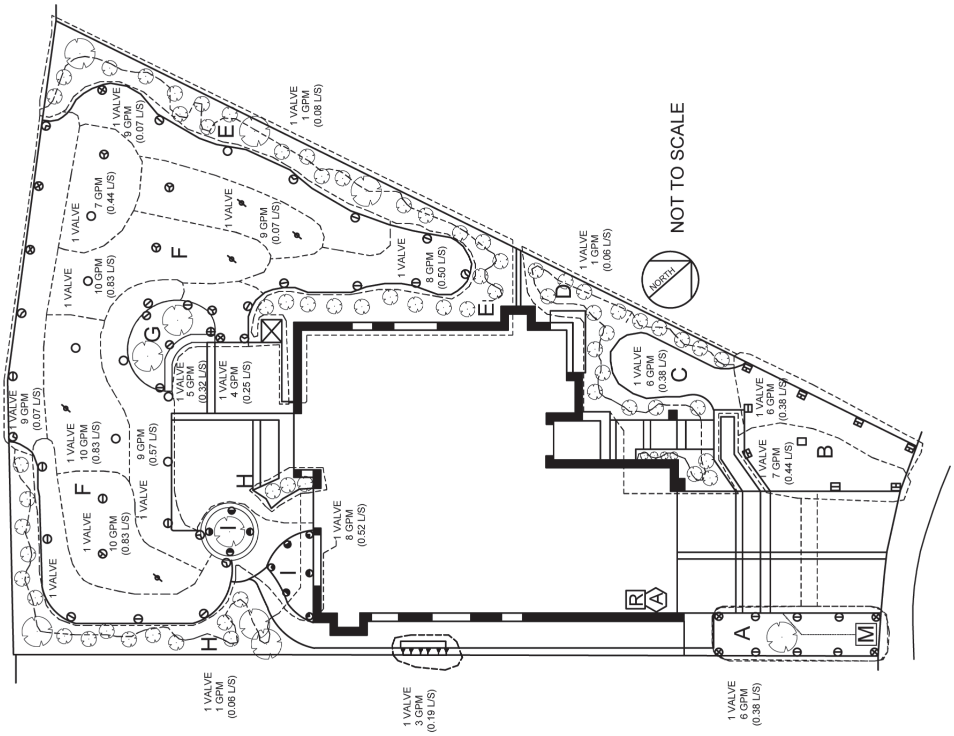
Step 4. Design circuit and valve group

Step 5. Plan detailed circuit

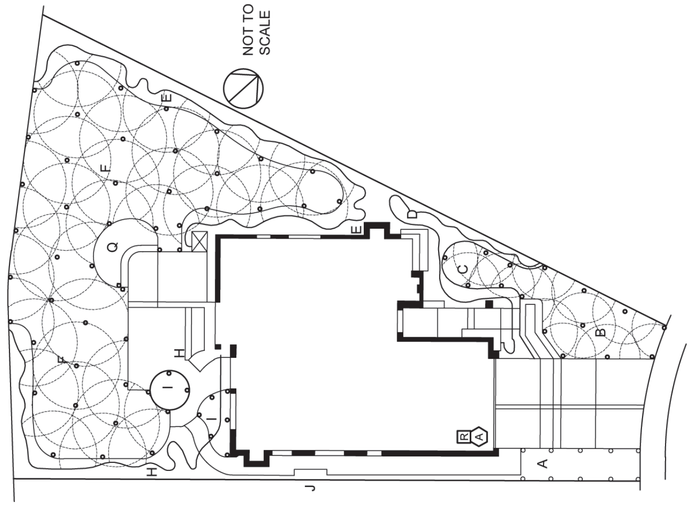
Step 6. Go through the plan and finalize the plan (Figures on pages 237-240)


NOTES,
WIND (10 HPH [36 KPH]), OUT OF NORTHWEST
CLAY LOAM SOIL
TREE LOCATIONS
SHRUB LOCATIONS
GRAVEL MULCH AROUND TREES/SHRUBS
BARK MULCH AROUND PERENNIALS
ELEVATION RISE OF 2 FT (0.6 M) FROM WATER METER TO GARAGE THE REST OF SITE IS FLAT FROM FRONT OF GARAGE TO BACK FENCE
BLOCK WALL
WROUGHT IRON FENCE
PERENNIALS
LAWN
PATIO
PERENNIALS
BLOCK WALL
LAWN
BLOCK WALL
PERENNIALS
GRAVEL
CLMBING PLANTS
GRAVEL
GATE
WALK WAY
DRIVE
WALK
LAWN
LAWN
3/4-INCH (20 mm.) COPPER SERVICE LINE
3/4-INCH (20 mm.) WATER METER
90 PSI (6.2 BARS) STATIC PRESSURE
M

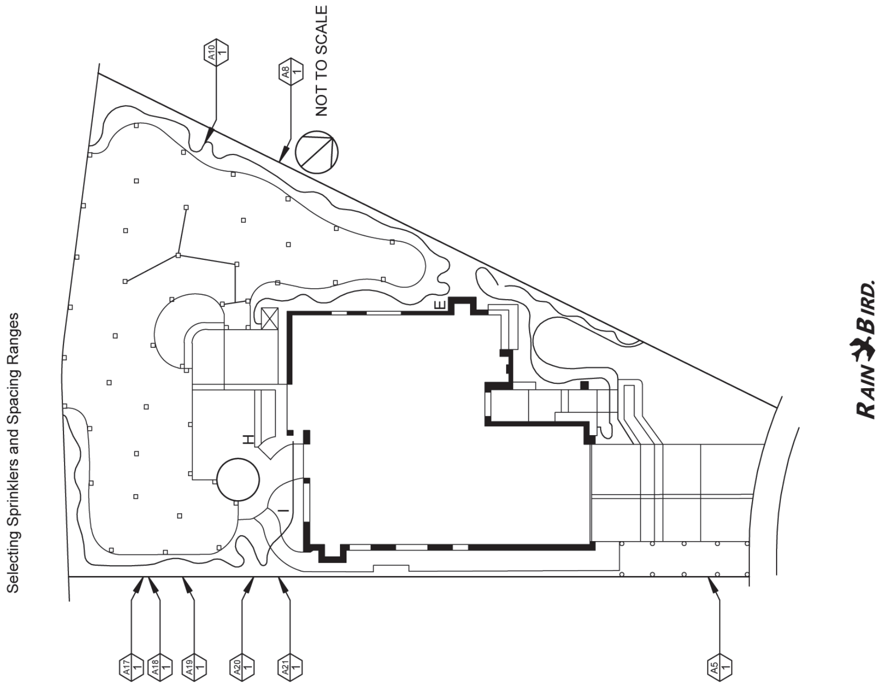




Lateral Layout, Circuiting Sprinklers in Valve Groups



Selecting Sprinklers and Spacing Ranges


Selecting Sprinklers and Spacing Ranges
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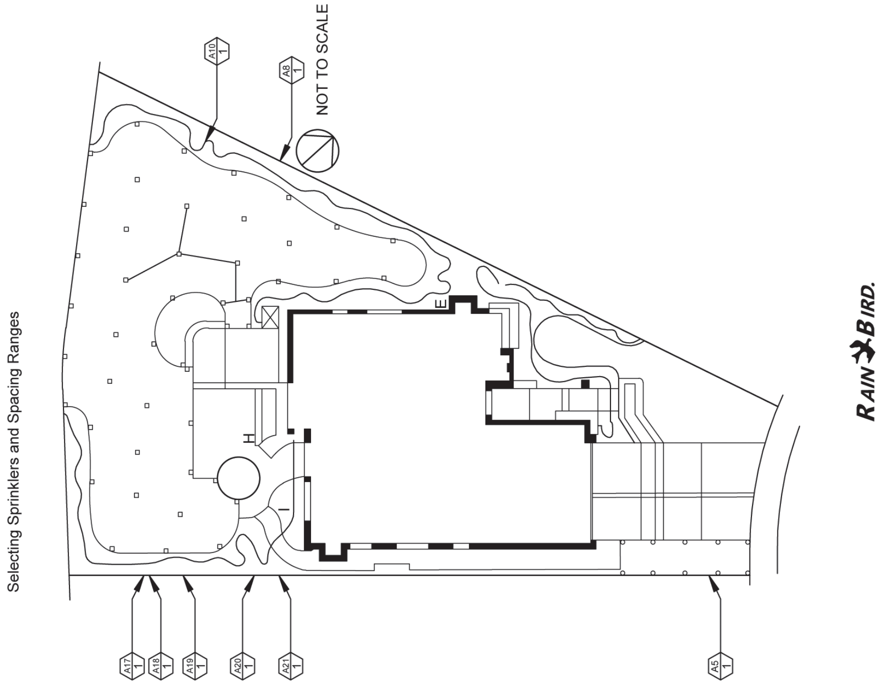
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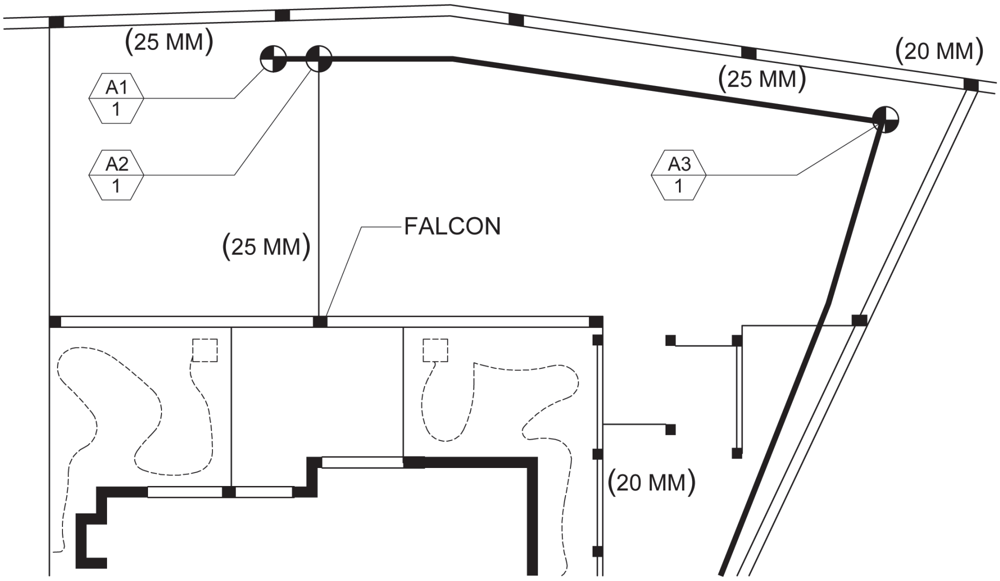


10.6 Concept about Xerigation

Xeriscape refers to landscape design that conserves water and reduces runoff by using plants that need less water. In foreign countries, runoff is a major concern because it may be contaminated with pesticides and fertilizers that adversely affect the public water ways. Xerigation is the word coined for this purpose. In the United States, according to one study, in an urban area 25% of water is used to water plants especially in summer. On average 60% of the water used by households was for landscape since the old irrigation system used a lot of water and the water was used inefficiently. There are seven principles of Xerigation.

1) Design and layout: Plant vegetation that needs the same amount of water should be put in the same area.

2) Soil analysis and preparation: Add organic fertilizers or manure so that soil can hold more water.

3) Functional lawn: Avoid too many lawns since they require a lot of water for maintenance.

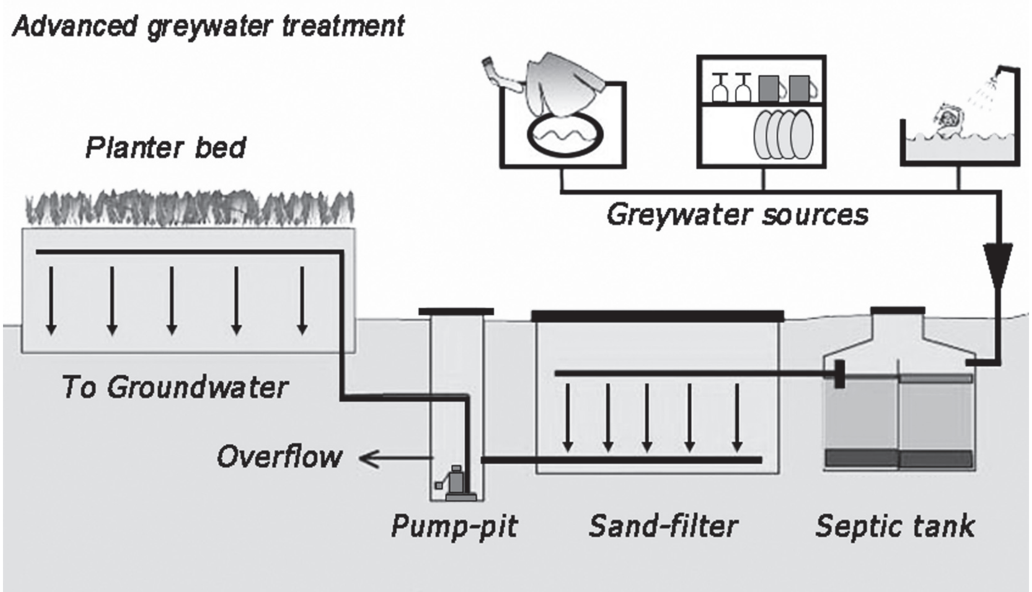
4) Suitable vegetation: Local vegetation should be used as it grows well in its surrounding.

5) Effective irrigation: Water plants sufficiently and effectively.

6) Suitable mulches: Cover the soil appropriately to maintain moisture in the soil.

7) Proper maintenance of landscape: Cut grass to enhance the arable soil, for instance.

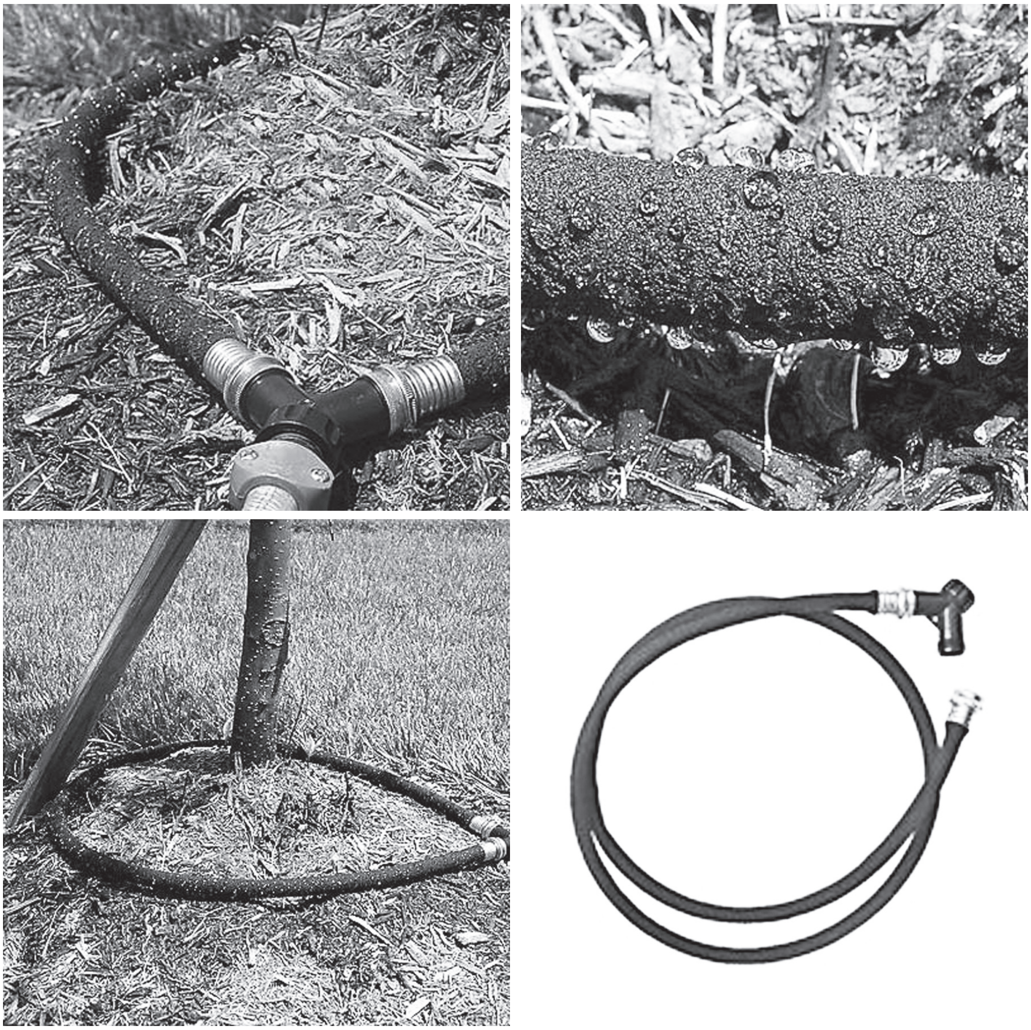
Irrigation has been developed along these lines. The sprinkler heads are developed to release less water and go directly to the plant roots. The leftover water will stay in the ground and not become runoff. If the water is sprayed, the water is in the form of large droplets because smaller droplets mean more loss of water through evaporation.



Source: *Adapted from Fastighetsanalys www.greywater.com*

Figure 10.4 *A diagram showing the recycling of wastewater to be used in the irrigation system*

In addition, green architecture concepts are integrated by recycling water (grey water) and storing rain water for future use (rain water harvest). Chapter 14 deals with this.



Source: *www.agriculturesolutions.com*

Figure 10.5 *An Xerigation system – directing water to the plant roots*


SAM: USE BOTTOM INLET

Lighting in landscape and architecture at the bridge in Suzhou

Chapter 11

Outdoor Illumination and Lighting

11.1 Preface

In the past, electrical engineers were responsible for electrical wiring systems and landscape architects chose the fixtures. However, in more recent times, electrical wiring systems and lighting have become increasingly related to landscape architecture in terms of enhancement. In addition, maintenance, safety and energy savings are also important. Landscape architects, therefore, have to understand technical terms about electrical devices so that they can make the right decisions concerning wiring and electrical devices to save project costs and maintenance in addition to blending them in with the other elements.

11.2 Types of electrical systems

Electrical conductors indicate how safely electric power is conducted and how much they can carry the power from one point to another. High electric potential means greater energy levels and that means higher risk of electric shocks. High electric potential will flow to low electric potential and the flow will stop when the potential become balanced. Different power sources distribute different amounts of charges, for example, a battery for a flashlight has potential difference at 1.5 volts while a battery for a car has potential difference at 12 volts and the electric wire in a house has potential difference at 220 volts.

Electricity can be divided into low voltage systems – the electrical pressure between phases is less than 750 volts – and high voltage systems – the electrical pressure between phases is more than 750 volts. The low voltage system and the high voltage system will not be wired together but are connected through an instrument transformer so that the proper power can be harnessed.

11.3 Electrical appliances and installation

The installation of fixtures and electrical appliances in landscape architecture is an art. The design of electrical wiring includes the specification of locations, wiring and control. The architects have to know technical terms and basic principles of electric systems so that they can design the system appropriately.

An electrical appliance refers to an appliance that changes electrical power into another form of power such as heat or mechanical so that appliances can be used such as light bulbs, air-conditioners and water pumps. An electrical device refers to the part of the electric system that carries the electric power. It does not use the power such as a switch or an outlet. The electrical devices and wires have to be manufactured to industry standards for example, by IEC, BS, ANSI, NEA, DIN, VDE, UL, JIS and AS. If not, for those electrical devices and the wires to be used one has to seek permission from the Provincial Electricity Authority. The devices include electric wires, conductors, protective devices, grounding electrode system and grounding replacement and conduits.

Other major terms (some of them are obtained from the online course NECTEC) are:

1. A switchboard can be a single board or multiple boards where devices are installed. The devices are switches and circuit breakers.

2. A panel board can be a single board or a group of boards that are installed in a cabinet against the wall. The board accommodates a circuit breaker, lighting control, heater and electric circuit.

3. A main switch refers to the control switch between main power line of the Provincial Electric Authority and the user's power line. The main switch includes a cut out switch and circuit breaker.

4. A feeder system that can be divided into:

   – the main service referring to the wire connecting the meter outside the house and the main switch.

   – the feeder referring to the wire connecting the main switch and the last circuit breaker in the minor circuit.

   – the branch circuit referring to the circuit between the last circuit breaker and the point where electricity is distributed to the appliance.

5. Grounding

6. A loading system can be continuous load referring to the continuous maximum load distributed for at least three hours and its ampacity – maximum amount of electric power that a conductor can carry continuously and safely. The load is measured in amperes.

Figure 11.1 *Switch board*

7. Electric system protection

– Insulation refers to the proper protection of wires and other devices according to their functions and whether they are waterproof but not dustproof or high temperature proof. The insulation can be an enclosure to protect the devices or the appliances from being damaged physically or a guard to prevent people or things from touching the devices or the appliances with the help of a box or fence.

– Exposure refers to unprotected live electric wires so an appropriate method to deal with this has to be undertaken.

– Dead front refers to the area where there is no exposure so a person can be in that area safely.

8. Accessibility includes the following:

– Accessible – A device can be accessed without any protection (a door with a lock, installation on a high shelf or through another method) or wiring that can be opened without damaging the building or the covering or wiring that does not touch the building or that is not permanently covered.

– Concealed – A condition where electrical devices cannot be accessed because a structure covers it. A wire in the conduit is considered concealed.

– Hazardous area – An area that can catch fire or explode because of inflammable vapor or fibers.

9. A wiring system consists of:

– Raceways referring to a tube or a passage that covers or holds the wires to facilitate wiring.

– Conduit referring to a round tube made of plastic (PVC, PE), electrical metallic tubing (EMT), intermediate metal conduit (IMC) and rigid steel conduit (RSC).

– Wireways referring to a tray that can be opened and closed with or without an air ventilation duct.

– Cable trays referring to open trays made of non-flammable materials to place wires. The trays are divided into a ladder tray, a solid-bottom tray and a ventilated tray that has openings in the bottom of the tray.

– Busways referring to a conductor with or without insulator. They can be like a sheet or a rod and grounding is required.

10. A branch circuit is used with lighting circuits, electrical appliances or both. They consist of:

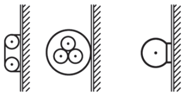
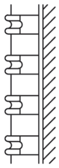
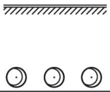
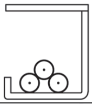
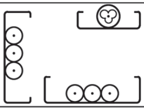
– A feeder that should be of appropriate size so that it can distribute enough power to the board, but it should not be smaller than 2.50 square millimeters.

– A neutral line that can carry maximum unbalanced load and harmonics load.

– Circuit breaker for the board and the feeder.

– There should be only one set of main cable that supply electricity to one uses. The main cables can be divided into the following:

(1) Above ground main line for low-voltage systems. This has to be insulated with the size of at least 2.50 square millimeters for a copper wire and at least 10 square millimeters for an aluminum wire. There are also requirements for interior wires.

No.	Electronic system	Figure
1	Above ground main line for low-voltage systems	
2	Above ground main line for high-voltage systems	
3	Underground main line for low-voltage systems	
4	Underground main line for high-voltage systems	
5	Direct underground main line systems	
6	Wireways main line systems	
7	Cable ladder line way systems	

Source: *www.nectec.or.th/courseware/electrical*

Figure 11.2 *Various types of wiring*

Figure 11.3 *Nonmetallic conduit is flexible according to the landform in the landscape architecture of Chulalongkorn University*

(2) Above ground main line for high-voltage systems. This can be bare or insulated and big enough to carry all the loads.

(3) Underground main line for low-voltage systems. This is an insulated copper wire at least 10 square millimeters in size.

(4) Underground main line for high-voltage systems. This is an insulated wire and big enough to carry all the loads.

11. A main switch consists of a disconnector switch and circuit breaker or an overload protective device that can act as a circuit breaker.

12. A main distribution board (MBD) is mostly found on the floor because it is very big. It varies in size according to purpose.

11.4 The design of electric systems in landscape architecture

Landscape architects are involved in specifying fixtures, wiring and control.

Wiring can be done by:

1. Surface wiring – Wiring low-voltage systems in the building.

2. Open wiring – Guy strain insulators are used and the wire has to be a single wire.

3. Wiring with rigid metal conduit, intermediate metal conduit and electrical metallic tubing – Can be used in general wiring works in dry, moist or wet area.

4. Flexible metal conduit – Wiring in a dry and accessible area to protect the wire from being damaged or to conceal the wire.

5. Liquidtight flexible metal conduit – To protect the wire from vapor, liquids or solids.

6. Nonmetallic conduit – Non metal conduit and its accessories have to resist moisture and chemicals. The above-ground conduit has to resist pressure and sunlight while the underground conduit has to resist moisture, and substances that cause corrosion and pressure.

7. Liquidtight flexible nonmetallic conduit made of non-flammable materials. It is round with no seams and use to keep wirings dry.

8. Surface metal raceways – Suitable for dry areas.

9. Surface nonmetallic raceways made of moisture and chemical resistant materials. These are also non-flammable, heat-resistant and can bear a lot of pressure. They can be used in low temperatures.

10. Metal wireways used in an open wiring. If installed in a wet area, a cover is required.

11. Busways must be installed in the open and be accessible in order for maintenance to be done.

12. Cable trays – The installation has to follow the instructions.

Electric connection refers to the connection of a conductor to other electric devices through various methods.

1. A grounding electrode system. The installation has to follow the safety measures required by the Department of Energy Development and Promotion. The installation of the grounding electrode system in commercial

buildings, factories and theaters has to follow the safety measures required by the Announcement of the Ministry of the Interior.

2. A box. There are many kinds of boxes depending on the purpose such as a switch box, a connection box or a division box.

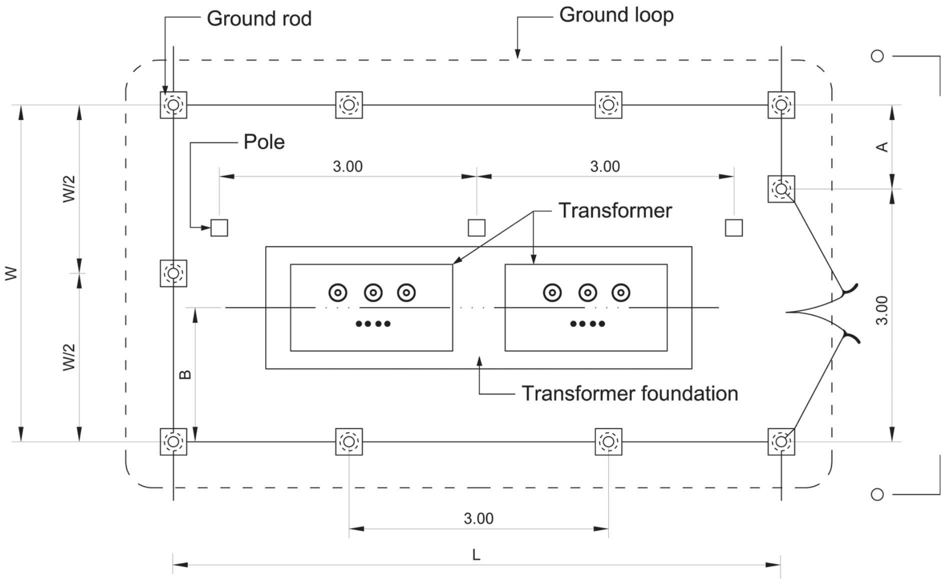
The location of a transformer

A transformer and its station have to be designated and be readily accessible for checking and maintenance. Sufficient ventilation is necessary.

1. A transformer yard is the ground covered with at least 10 centimeters thick rocks except in the places where the devices are.

2. A transformer has to be in an enclosure that is a wall or a fence with a lock. Only responsible staff can gain access to it.

A high-voltage system has to be at least 275 centimeters above the ground except when there is a protective part to guard against electrical shock. The horizontal spacing should be at least 1.80 meters from the system and at



Source: *www.nectec.or.th/courseware/electrical*

Figure 11.4 *Area preparation for a transformer enclosed with 2–meter–high wire mesh* least 1 meter from the transformer. The spacing between each transformer should be at least 60 meters and the protective fence should be at least 2.13 meters high. A warning sign should be visibly located.

11.5 Lighting and illumination

Lighting should be adjusted according to specific function while illumination can focus on aesthetics – effect lighting or accent lighting. In addition to function, an illumination system concerns visibility, atmosphere and harmony.

11.6 Lighting design and illumination

Lighting can be classified into primary lighting systems and secondary lighting systems.

1. Primary lighting system refers to lighting systems that serve specific purposes that can be further divided into:
   - General lighting referring to the general distribution of light throughout the whole area. Aesthetics is not the major concern; therefore, energy savings should be administered here.
   - Localized lighting referring to an area where intense lighting is assigned to a particular area.
2. Secondary lighting system refers to lighting systems that focus on aesthetics. The secondary lighting system can be further divided into:
   - Accent lighting focusing on a certain object to attract attention.
   - Effect lighting creating a cozy atmosphere such as a ceiling lamp to create a pattern on the wall.
   - Decorative lighting from lamps to highlight interior decorative items.

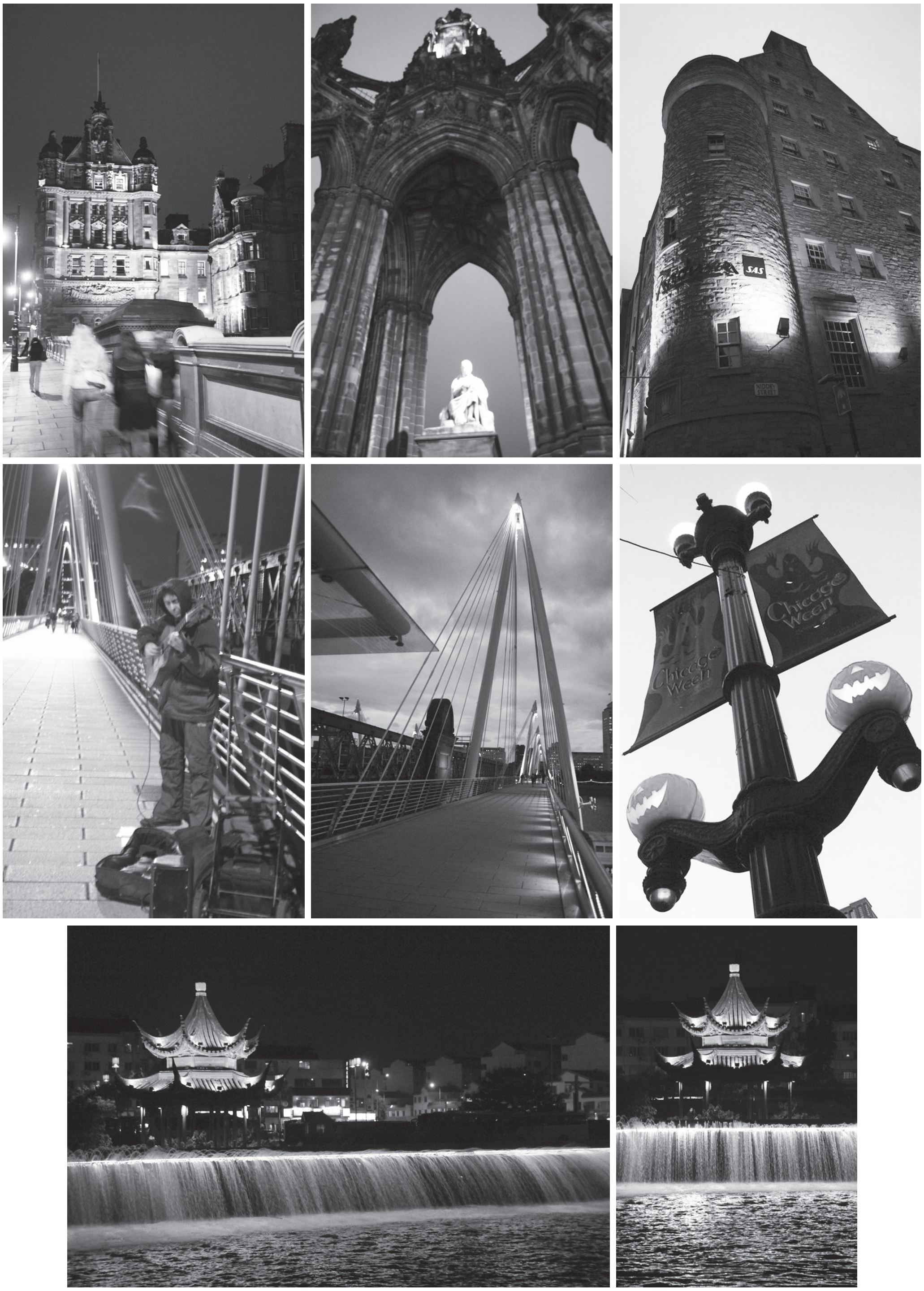


Figure 11.5 *Lamps and lighting in urban landscape architecture such as lighting in architecture, landscape architecture and lighting for safety*

– Architectural lighting or structural lighting such as illuminating the building at night.

– Mood lighting requiring a switch to dim the light for a desired atmosphere to be obtained.

Since illumination systems in landscape architecture are carried out in the open or public places, landscape architects should conduce the quality and safety of fixtures and accessories, their proper location and maintenance. Plus, they have to serve the users' needs; as a result, universal designs are key.

11.7 Lamps

Lamps can be divided into:

1. Incandescent lamps that can be further divided into incandescent lamps and tungsten halogen lamps.

2. Gas discharge lamps that can be further divided into low pressure discharge lamps such as fluorescent lamps, compact fluorescent lamps and low pressure sodium lamps and high pressure discharge lamps such as mercury vapor lamps, high pressure sodium lamps, metal halide lamps and outdoor bulbs.

2.1 Low pressure sodium lamps are for street lighting or for general purposes because of poor color rendering and it takes a long time to light up feelly so they should not be used in an area where immediate lighting is needed.

2.2 Mercury vapor lamps are the least efficient gas-discharge lamps that are suitable for factories, streets, public parks and shops. They are not suitable for an area where immediate lighting is needed.

2.3 High pressure sodium lamps offer poor color rendering and they are suitable for streets, public parks and non-commercial zones. Some improvements have been made to these lamps so they can be more widely used because of better color rendering. These lamps are the most efficient high

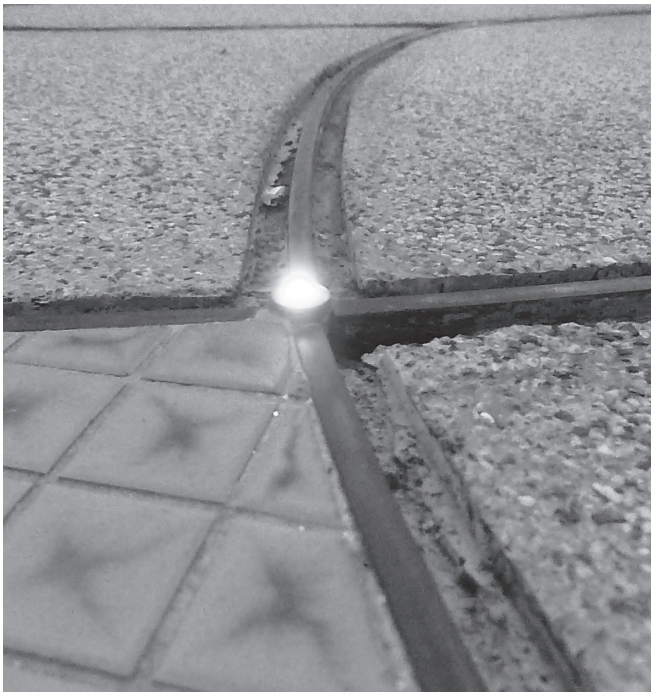


Figure 11.6 *Lighting through optical fibers from a light source*

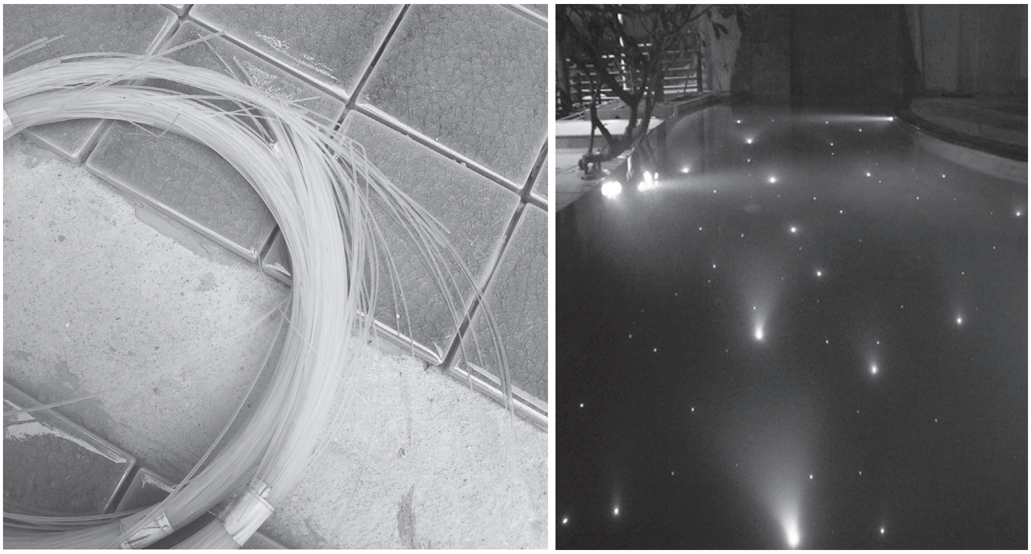


Figure 11.7 *Joining of optical fibers in a swimming pool and lighting characteristics*

pressure lamps. They produce yellow light which is easy for the eye to see, so they are suitable for jobs that require safety.

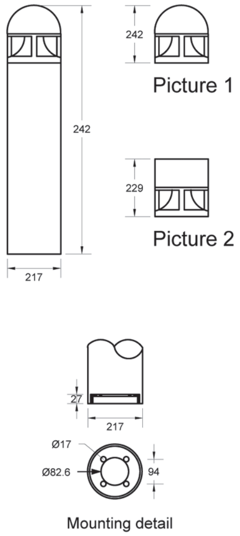
2.4 Metal halide lamps are suitable for factories, sports terrain and areas that require proper lighting, but they are not suitable for areas that require instant lighting.

At present, fiber optics are used in lighting and they can create many kinds of lighting.

11.8 Choosing lamps

Factors for consideration in choosing lamps are as follows:

1. Luminous flux refers to the amount of light a lamp produces. This is measured in lumen.
2. Luminous efficacy refers to the amount of light per watt. This is measured in lumens/watt (lm/w).
3. Color rendering refers to the shade of color an object produces when exposed to lamp light. This is measured in percentage.
4. The color temperature of a lamp. This is measured in Kelvins.
5. Burning position refers to the direction at which a lamp should be set according to the manufacturer's requirements. This affects certain types of lamp.
6. Life refers to the average life of a lamp. This is measured in hours.
7. The site will determine the properties of the lamp.
8. The temperature can determine the properties of the lamp. Some cannot be used in low temperatures or offer small amounts of light.
9. The operating characteristics such as start-up time, restart time and dim-light time.
10. Cost includes expenditures on investment and maintenance.

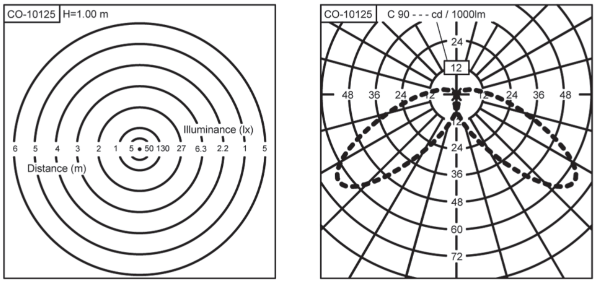


CO-101

Columbus bollard

IP55 /EN 60598 / CLASS I / /CE/IK 08

PHOTOMETRIC DATA



Columbus bollard

	Model No.	Lamp	Holder	Lumen	Weight	(H) Height	Picture	CCG	*ECG
☐	CO-10111-1	TC-D 18w.	G24d-2	1800	8.4 kg.	724 mm.	1	*	*
☐	CO-10112-1	TC-D 26w.	G24d-3	1800	8.5 kg.	724 mm.	1	*	*
☐	CO-10114-1	HIE 70w.	E27	4900	8.9 kg.	724 mm.	1	*	*
☐	CO-10115-1	HSE 70w.	E27	5600	8.8 kg.	724 mm.	1	*	*
☐	CO-10111-2	TC-D 18w.	G24d-2	1200	8.4 kg.	711 mm.	2	*	*
☐	CO-10112-2	TC-D 26w.	G24d-3	1800	8.5 kg.	711 mm.	2	*	*

LIGHTING SIMULATION

Source: *Ligman Lighting*

Figure 11.8 *Examples of light bulbs and lamps from a catalog. Outdoor bulbs have details such as IP rating, height, type, lumen, photometric data, and lighting simulation.*

Table showing illumination and quality of light

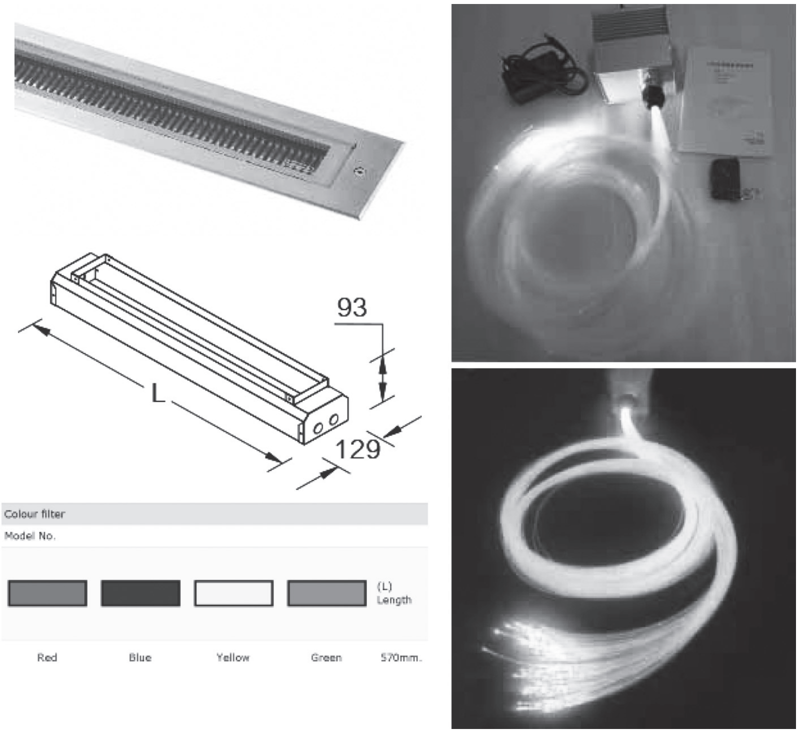
Area	Lux	Kelvins
Walkway	50	2,600/4,000
Parking lot	50	2,600
Garden	50/150	4,000

Table showing illumination and roads in different areas (Lux)

Road	**Downtown**	**City**	**Upcountry**
Secondary road	300/700	200/500	150/300
Major road	700/1,000	500/750	400/600
Main road	1,000/7,000	750/5,000	600/1,000

11.9 Types of Lamp

Both indoor and outdoor lamps can be fluorescent, up light, factory, high pressure discharge, flood light and downlight. They can be found in incandescent lamps, compact fluorescent lamps and high pressure discharge



Source: *Ligman Lighting, Tlsanli Lighting*

Figure 11.9 *An LED bulb buried in the floor with a color filter and in an optical fiber with a light source* lamps. Downlights are for general purposes while flood lights are for structural lighting or big areas such as sports ground, parking lots, construction sites and uploading/downloading areas of merchandise.

A light emitting diode (LED) is a device that transforms electric signals into light signals so that light can go through an optical fiber and a LED Floof light uses an LED lamp that saves energy and provides a lot of light covering a large area. LED lasts longer and can be use to alter the wall colour of a building wall. It is suitable for a large area.

11.10 Factors to be considered in the selection of lamps and bulbs

Landscape architects have to consider the following:

1. Safety of lamp
2. Luminaire efficiency
3. Coefficients of utilization
4. Glare
5. Distribution Curve
6. Ventilation
7. Life
8. Location
9. Ingress Protection (IP) ratings. The IP ratings are in Document 60529 developed by the International Electro Technical Commission (IEC). The IP rating normally has two numbers. The first number represents protection against small objects (dust) or materials. The numbers range from 0 to 6.

0 = no special protection

1 = protected against solid objects over 50 mm. e.g. accidentally touched by a person's hands

2 = protected against solid objects over 12 mm. e.g. a person's fingers

3 = protected against solid objects over 2.5 mm. e.g. tools or wires

4 = protected against solid objects over 1 mm. e.g. tools or small wires

5 = partial protection against dust

6 = totally protected against dust

The second number represents protection against liquids. The number ranges from 0 to 8.

0 = no protection

1 = protected against vertically falling drops of water

2 = protected against direct sprays of water up to 15° from the vertical

3 = protected against direct sprays of water up to 60° from the vertical

4 = protected against water sprayed from all directions

5 = protected against low pressure jets of water from all directions

6 = protected against temporary flooding of water e.g. rain or for use on ship decks

7 = protected against the effect of immersion of between 15 cm. and 1 m.

8 = can be ured underwater

Sometimes the IP rating has 3 numbers and the third number represents impact protection which is rarely used. There are other standards such as NEMA Enclosure Types developed by the National Electrical Manufacturers Association (NEMA).

Table 11.1 Comparison of NEMA Enclosure Types and IP Ratings

Condition	NEMA	Compared with IP Code
None-protection	0	IP00
General	1 1**	IP3 IP2
Waterproof	2 2**	IP31 IP21
Waterproof, dust-proof, hailstone-proof	3	IP66* Rust-resistant
Waterproof, hailstone-proof	3R 3R**	IP34* Rust-resistant IP24* Rust-resistant
Waterproof, dust-proof, hailstone-proof	3S	IP66* Rust-resistant
Waterproof, dust-proof	4	IP66* Rust-resistant
Waterproof, dust-proof, corrosion-proof	4X	IP66* None-corrosion
Waterproof, dust-proof	6	IP68
Waterproof, dust-proof	12	IP65
Oil-proof, dust-proof	13	IP65 Oil-gasket included

** Protection against hail according to IEC 144 is not specified*

*** Heat ventilation*

Source: *www.nectec.or.th*

An example of an interior landscape in an accommodation. The choice of plants depends on light and area proportions

Chapter 12

Interior Landscape

12.1 Preface

At present, the landscape is increasingly intergrated into architecture and interior architecture due to the introduction of vegetation, water, gravel and stones to the interior of the building to create a natural atmosphere. Plants also provide the building with oxygen. The very first work of interior landscape architecture was a garden in the building of the Ford Foundation in New York by Dan Kiley. This was considered the first garden design in a commercial building and the biggest at the time (Hammer, 1991). Energy saving is another issue because trees or plants can replace air conditioners, reduce the release of carbon dioxide and create a pleasant atmosphere. This uses landscape as air purification and air conditioning. However, there are some constraints in interior landscapes. This unit will give some ideas about the interior landscape for further applications.

12.2 Interactions between man and interior environment

The report "Interior Landscape Plants for Indoor Air Pollution" by NASA and the Associated Landscape Contractors of America (ALCA) (Wolverton, Johnson and Bounds, 1989) describes the interactions between man and interior environment, the exchange of carbon dioxide and oxygen – especially the absorption of harmful chemical substances – and the release of good chemical substances. This is a way to treat sick building syndrome. In addition, plants that can absorb harmful chemical substances in the building especially carbon monoxide and volatile organic chemicals (VOC) such as benzene, trichloroethylene (TEC) and formaldehyde are listed. This report has influenced building design since the late 1990s and green buildings also focus on reducing pollution in buildings and energy savings by using plants; therefore, interior landscape is gaining in importance.

12.3 Components of interior landscape

The interior landscape design depends on the type of building and its function such as a commercial building, an atrium of a building, a hotel, a department store, an office, a restaurant, a building in a botanical garden, a zoo or a museum. The major components of the interior landscape design are vegetation, pots/containers, irrigation and lighting. The minor components are Lampy, fountains, chairs and furniture.

12.4 Factors involved in interior landscape design

As mentioned earlier, an interior garden is beneficial and popular; as a result, there are some issues to be considered when designing this garden. The following factors are itemized according to their importance.

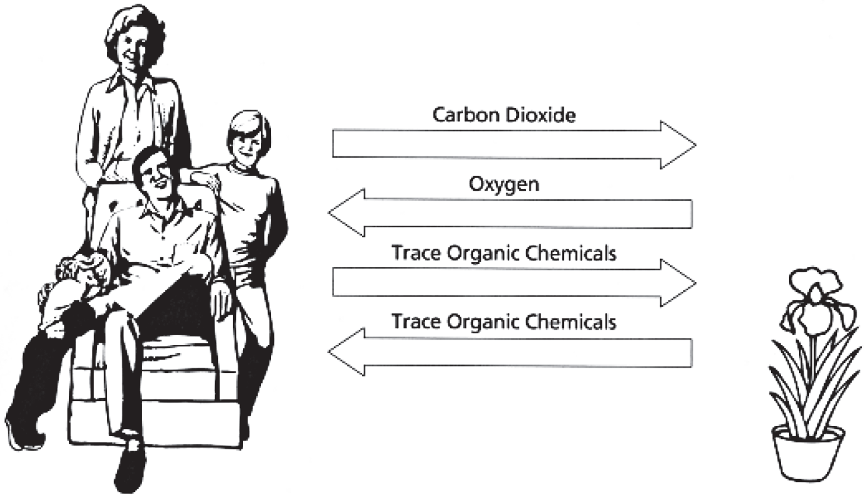


Figure 12.1 *Figures taken from the article "Interior Landscape Plants for Indoor Air Pollution Abatement" by Wolverton, Johnson and Bounds, 1989. They reveal the interaction between man and interior surroundings, the exchange and absorption of chemical substances and the release of chemical substances that are human friendly.*

Source: *Wolverton, Johnson, and Bounds, 1989*

1. Containerization. This factor is different from that of the exterior landscape design in that each plant has to be in a proper container which will limit the growth of plant.

2. Irrigation. Plants in buildings depend totally on watering system for water.

3. Water proofing. Good containers can prevent water from seeping so the floor or an object near the containers will not be damaged.

4. Light & glazing. Artificial light is not suitable for the plants so the lighting/characteristics of light are important in terms of intensity, duration and quality. Lighting can affect the existence of plants and atmosphere in terms of:

   – Transparent effect and translucent effect. These determine the distribution and intensity of light. The transparent effect can readily direct light to one spot creating a hot spot.

– Fluorescent lighting effect and incandescent lighting effect determine the intensity, softness and temperature of light. The fluorescent lighting effect offers a softer light that has a lower temperature.

– Diffused source and point source. The former distributes light like natural light while the latter does not.

– Photoperiod. The design of the clearstory has to be in line with the photoperiod and the locations of plants. The interior landscape mostly receives light from a skylight between 10.00 and 14.00, whose intensity is high and lasts a very short time.

– Natural light, skylight light and electric light. These have different properties. Even though most plants in the building can survive in a canopy with skylight light and electric light, they still need natural light for photosynthesis.

5. Temperature. Plants in the building can cause the greenhouse effect through transpiration. The temperature in the building usually ranges from 18°C to 26°C.

6. Humidity. The humidity in the building is less than that outside the building because of air conditioning. With air conditioning, the humidity in the building is at 20%.

7. Dormancy/hibernation of plants. The plants in the building are rarely exposed to natural light so their life cycle is different from those in the natural surroundings.

8. Maintenance of plants. Proper maintenance can extend plant life.

9. Design theory. Factors related to design will be further discussed.

12.5 Interior landscape design and limitations

In designing a landscape inside a building, the architect must be aware of its limitation as this can affect plants and other landscape components. The physical limitations in the building comprise:

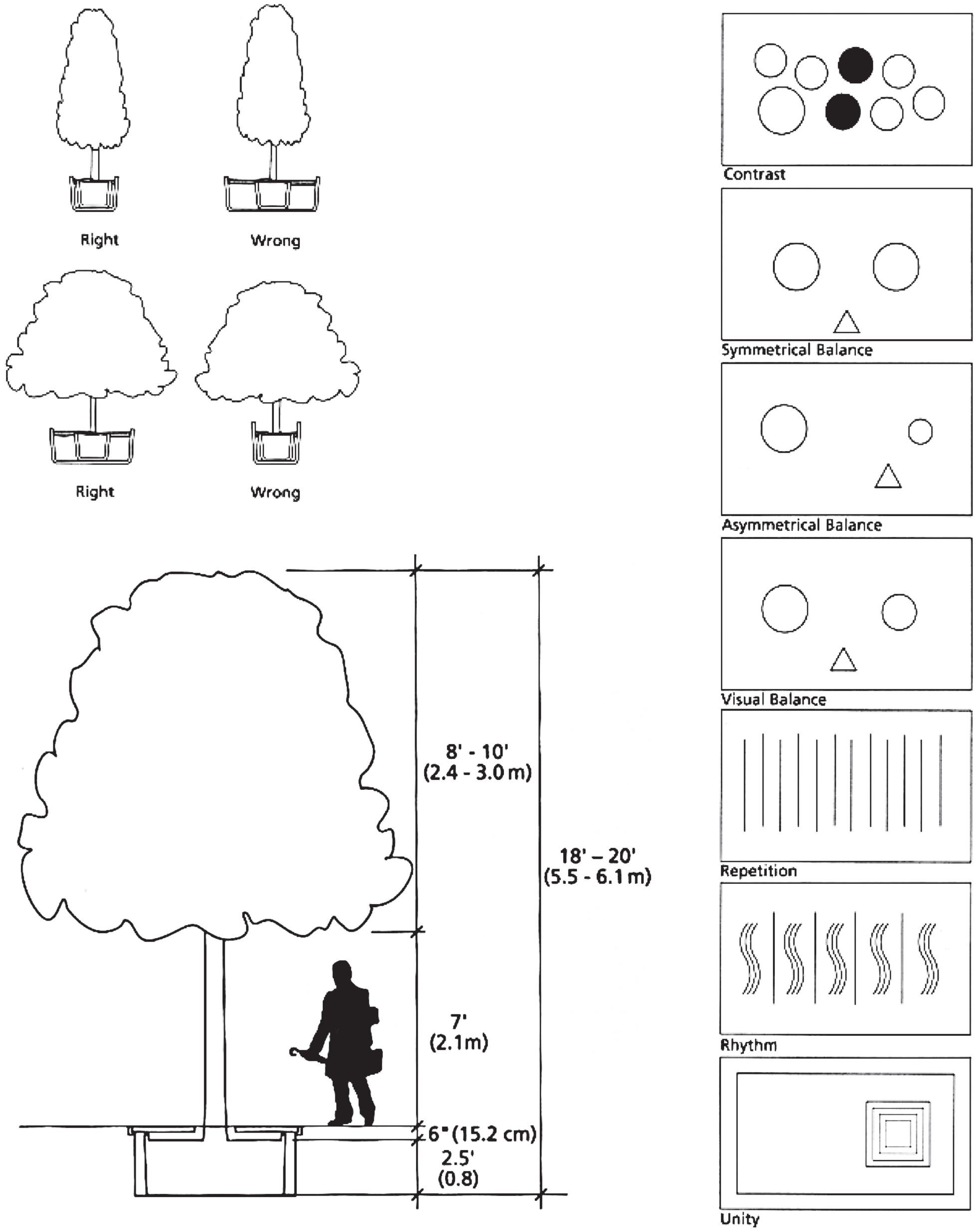


Figure 12.2 *Interior landscape design theory*

1. The area inside a building is already surrounded vertically and horizontally by roofs, corridors, wall and other components of the building. Therefore, plants and other components of interior landscape are secondary. So in designing and positioning one must consider the problem it could cause and how to position it to give different moods such as opposite, balanced, repetitive rythmic as can be seen in Figure (left).

2. Height specification based on the 2/3 rule referring to the height of the interior landscape being two-thirds of the height of the ceiling. The calculation is based on the maximum height of mature plants. In the composition of plants, there should be a focal point; for example, a 45 centimeters shrub should be placed among 10 centimeters ground covers. The shrub will be the focal point.

3. Choices of plants. There are certain types of plants that can survive in the building environment. One of them is the Ficus.

4. Colors of plants. There are options to choose from – expensive flowering plants mult be frequently change, and foliage with different color leaves together with green plants. The second option is cheaper in the long run.

5. The texture of leaves can create a close-to-nature atmosphere.

6. The habits of growth and forms. The plants in the building grow more slowly than usual and the forms are taper, cylindrical or triangular.

7. Ground covers act as the background of the composition. The ground covers can be plants or decorative mulch such as gravel, stone, tree bark, marble or sand.

8. A tree grate is fitted to the trunk of the tree so one can walk under the tree while trees can still draw water and air to its roots. The measurement of the clearance level below the front branch or leaf differs between trees inside and outside of the building. Outside the building it is the gap from its below branch or leaf to soil level whereas inside the building, it is the gap between the lowert brends and the ground level that people walk which could be lower (see Figure).

9. Containers can be:
    1. The top of a floor slab
    2. A built-in planter
    3. A dropped planter
    4. A bottomless planter
    5. A tree grate with bottomless planter
    6. A tree grate with concrete bottomed pit
    7. A balcony planter that can be further divided into:
        7.1 Balcony planting railing
        7.2 Balcony planting with liner attached to floor slab
    8. A decorative planter

Figure 12.3 *Problems about maintenance, air from air conditioners, irrigation and light lead to the replacement of real plants with artificial plants. The Figure shows the entrance hallway of Siam Paragon designed by Patrick Blanc.*

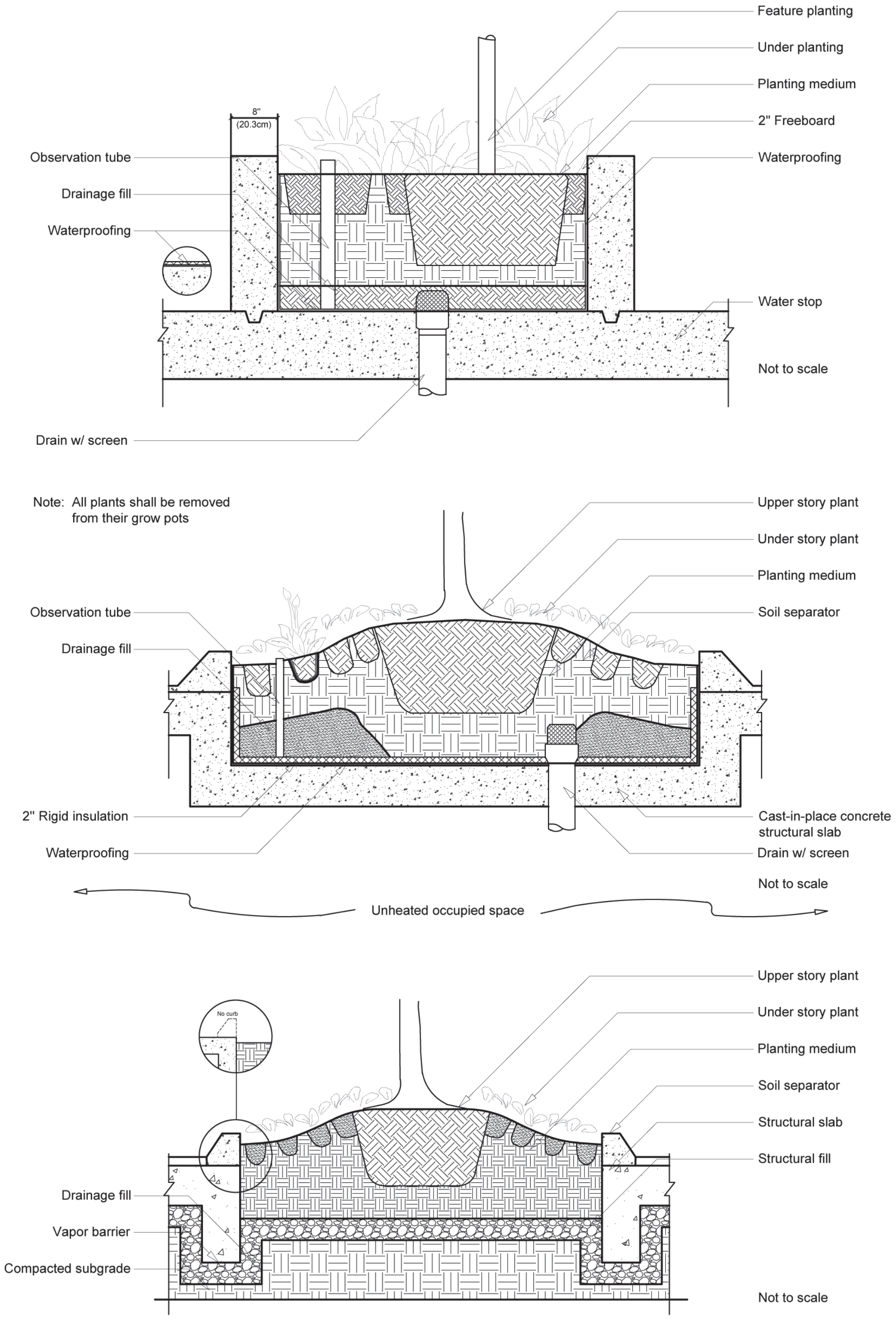
10. Dry plants or artificial plants. Use of dry or artificial plants is a controversial issue since real plants outweigh artificial plants in terms of benefits, but real plants are more expensive in terms of maintenance. However, artificial plants are applicable in an area where the light is dim, the temperature is not suitable for real plants, poor accessibility, the weight bearing is limited and safety is difficult to implement (such as in a factory). Landscape architects should consider users' benefits as priority – creating an atmosphere that alleviates sick building syndrome.

11. Vandalism and unintended damage and safety concerns choosing materials that are not harmful to children or can be torn easily.

12.6 Steps designing an interior landscape

1. Site analysis. Like exterior landscape design, the site of the interior landscape design has to be analyzed but the focus should be on lighting and other limitations (mentioned in 12.4 and 12.5).
2. A conceptual plan includes interior circulation, visibility, locations of plants that correspond to the site analysis.
3. Working sketch/planting plan
4. A planting plan schematic design refers to choosing the right plants and the right containers that are in line with the supply of light and water.
5. A design development planting plan
6. A detailed design that takes building structure, location, containers, infiltration resistance and drainage, engineering work, safety and maintenance into consideration
7. A dimension plan
8. A grading plan
9. A planting plan
10. Engineering work such as fountains, waterfalls, lighting and irrigation

Figure 12.4 *Interior landscape of the passenger building in Cenair Airport, Nagoya. The design simulates exterior surroundings such as the waiting area under the tree and the shopping area that is like the area in the old city.*



Source: Nelson Hammer, 1991

Figure 12.5 *Types of plant containers for interior landscape* *(continued on opposite page)*

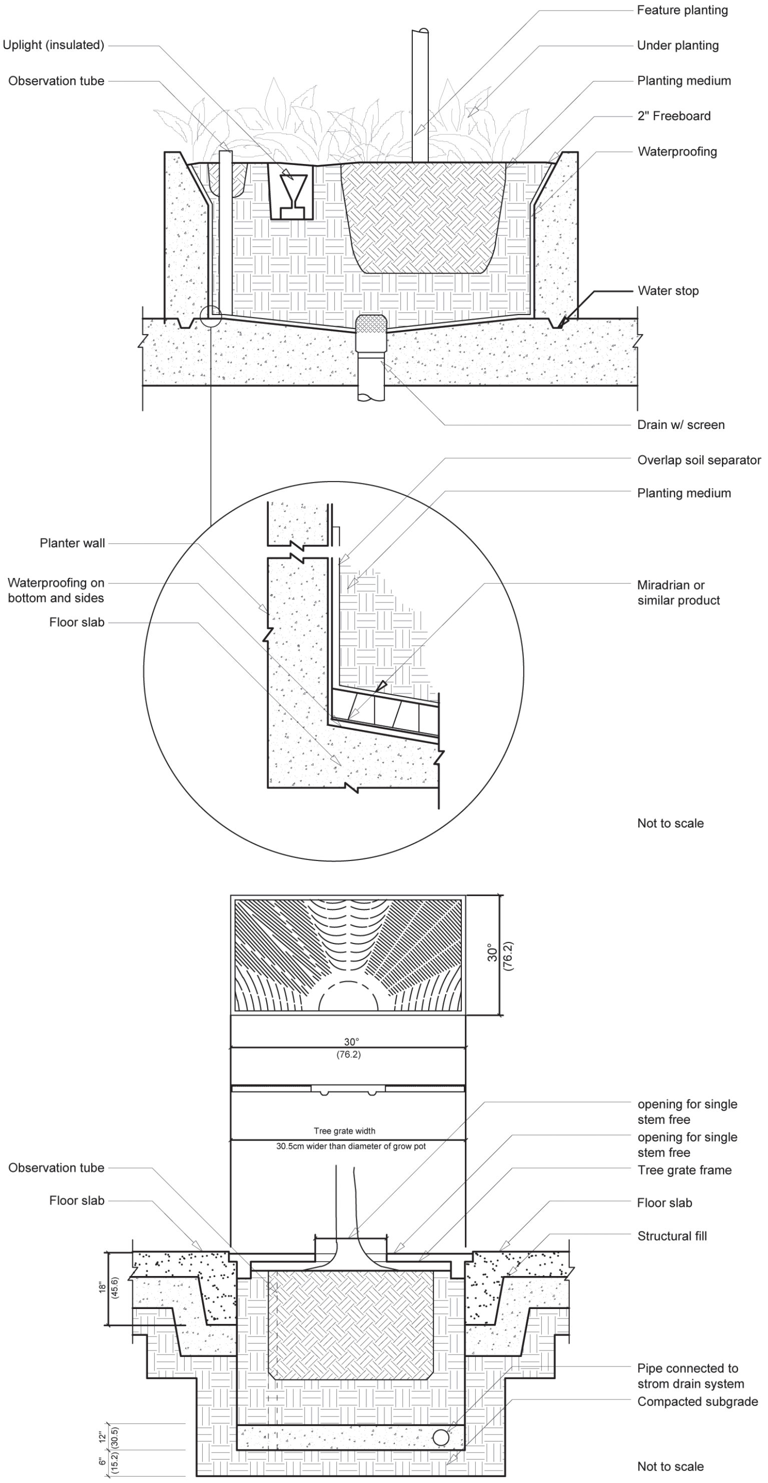

Feature planting
Uplight (insulated)
Under planting
Observation tube
Planting medium
2" Freeboard
Waterproofing
Water stop
Drain w/ screen
Overlap soil separator
Planting medium
Planter wall
Waterproofing on bottom and sides
Miradrian or similar product
Floor slab
Not to scale
30°
(76.2)
30°
(76.2)
Tree grate width
30.5cm wider than diameter of grow pot
opening for single stem free
opening for single stem free
Observation tube
Tree grate frame
Floor slab
Floor slab
Structural fill
18"
(45.6)
Pipe connected to strom drain system
Compacted subgrade
12"
(30.5)
6"
(15.2)
Not to scale

Figure 12.5

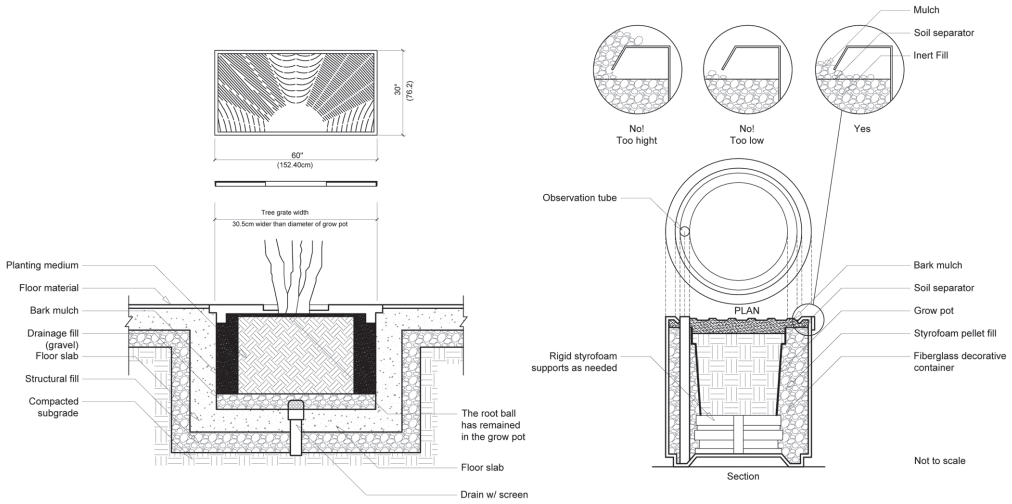


Figure 12.5

12.7 Watering systems and irrigation for interior landscapes

Since the environment in the building does not lend itself to the growth of some plants, watering systems and irrigation play an important role in interior landscape design and can be divided as follows:

1. Manual watering requires piping or a room in which to store watering tools.
2. Drip irrigation.
3. Automatic irrigation and micro irrigation.
4. A capillary action/wick system that is equipped with a vacuum sensor system to control the amount of water.
5. A sub-irrigation system gives water to the plant roots. The advantages are that the plants can absorb the water immediately. This saves water and the chance of overflow is very minimal.
6. Hydroponics is suitable for certain plants. It is also a method of growing plants and pests can be controlled to a certain level.

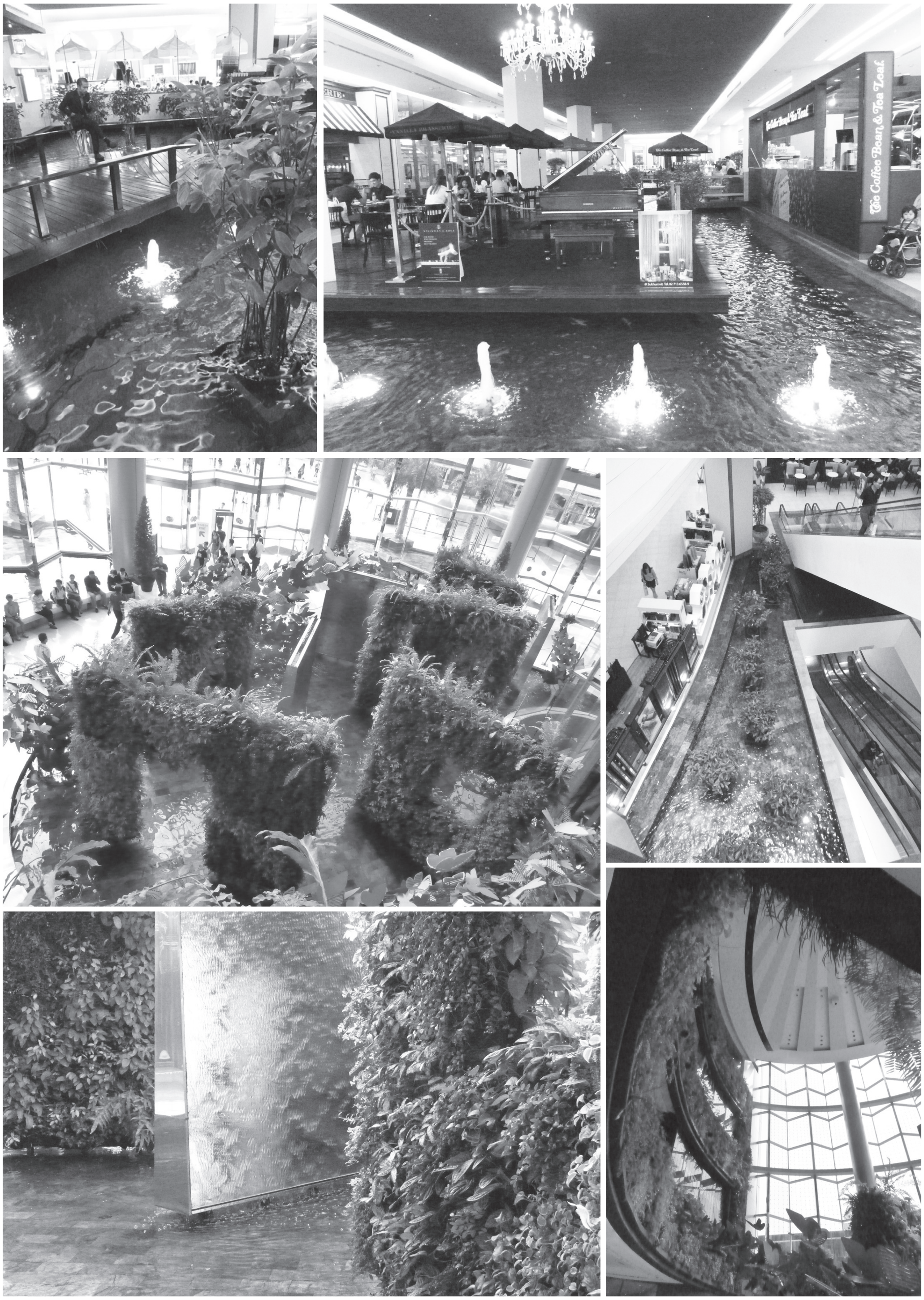


Figure 12.6 *Interior landscape in Siam Paragon includes plants, irrigation, and electric systems that create a pleasant atmosphere in the hallway.*

Figure 12.7 *Interior landscape design in an office in Denver harnessing natural light through prism rods creating a rainbow over the violinist*

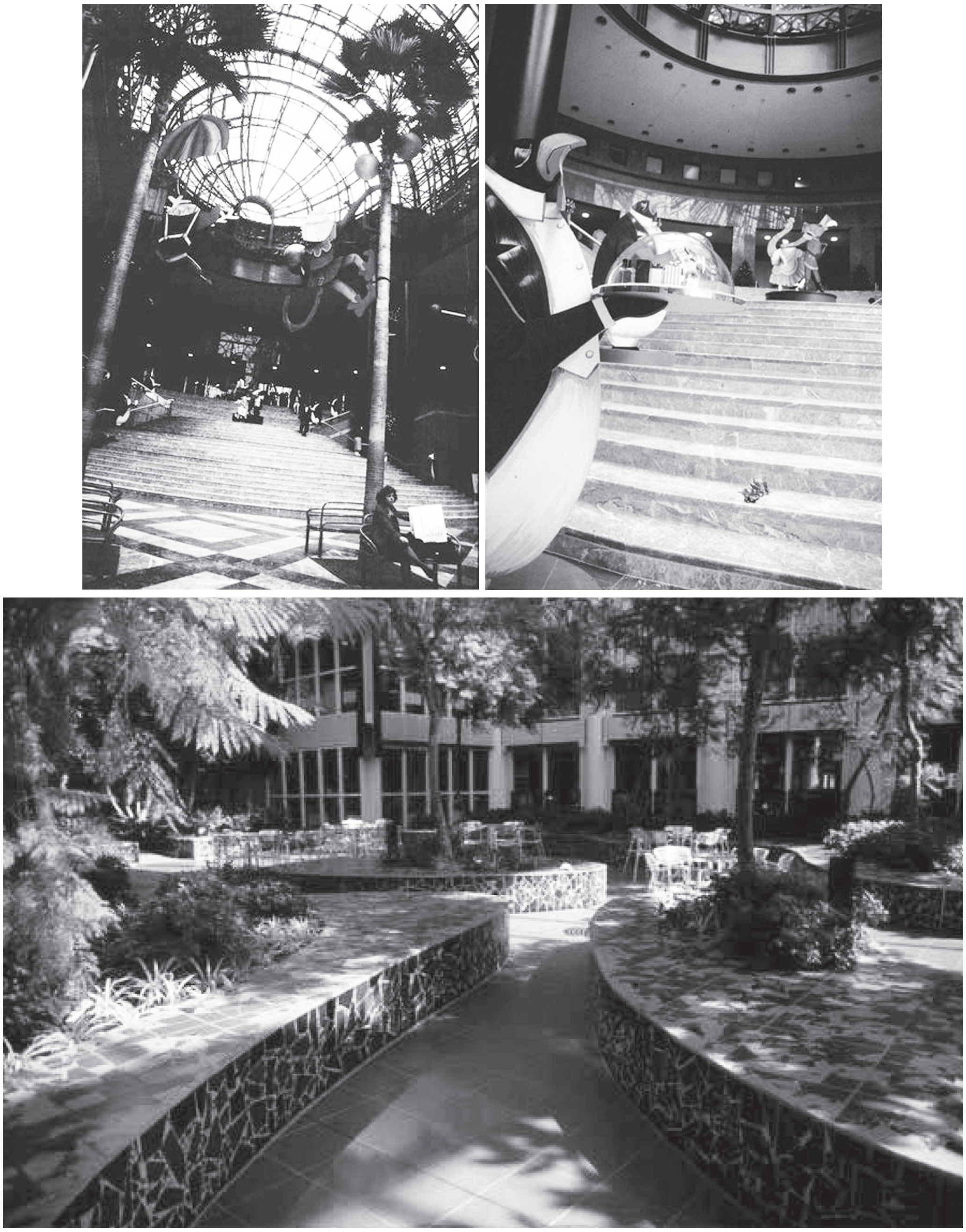


Figure 12.8 *A famous interior landscape design of the World Financial Center called Winter Garden (Below) – The Ministry of Housing, Spatial Planning and the Environment (VROM) in the Netherlands*

12.8 Interior landscape maintenance

Control or maintenance rooms are required for engineering systems; as a result, landscape architects have to decide where the rooms should be. The maintenance of the room housing watering system or watering tools (for manual watering), switches controlling the fountain system and lighting devices. There should be a room for storing a hose, watering equipment, fertilizers, pest control drugs, equipment for cleaning leaves, cutters, steps, wheelbarrows for carrying plants, garbage bins and washing tubs. The drainage pipe is 2 meters x 4 meters. Those who are in charge of plants and their components have to be assigned and a budget for maintenance has to be allocated.

Example of a roof garden in the Sentul residential project designed by Seksan

Chapter 13

Roof Garden, Green Garden

13.1 Preface

Originally, the roof garden accentuated function and aesthetics, but now it is also a way to solve energy and climatic problems as witnessed by the approval of the US Green Building and the Leadership in Energy and Environment Design (LEED). The Urban Redevelopment Authority of Singapore also uses this method to solve problems about urban expansion and development. It offers green roofs bonus gross floor area – GFA/LUSH – Landscaping for Urban Spaces and High-Rises to buildings with green roofs. Roof garden designs are included in the structural designs in Singapore.

Currently, the term, green roof, refers to a roof garden and roof designed for growing plants and catching rain water. This can be considered a design for the environment and urban water management to reduce impervious urban areas. In addition, more oxygen is produced and this saves energy since air conditioners are not used.

13.2 Roof gardens and the urban ecological system

The roof garden enhances a good environment in the urban areas and urban ecological system. The roof garden offers the following benefits:

1. Reduction in urban heat island effects and canyon effects. Few green areas are found in the city so the surface temperature is higher than the surrounding areas covered with trees by 2-5°C depending on the construction materials. The albedo and the thermal radiation differ according to the materials. The air conditioning in a building also releases heat to the surrounding areas and tall buildings in the city obstruct the heat transfer by natural wind; therefore, heat accumulates in that area and spreads out. The evapotranspiration of plants in the forest can lower the temperature of a forest so this concept is used in urban areas through the roof garden.

2. Reduction in storm water runoff management. The roof garden can absorb water in the city. Buildings and paved areas promote effective impervious areas and urban heat islands. Storm water runoff can cause floods, river bank erosion and soil erosion. The roof garden is a simulation of natural pervious areas.

3. Increase in economic benefits and aesthetics. Landscape architecture can turn a regular roof into a more functional roof such as urban agriculture – raising plants for consumption and it can also be used for relaxation. The roof garden can add value to a building especially one that overlooks another roof garden. Green roofs bonus gross floor area (GFA) adopted by the Singaporean government helps increase floor areas (Figure 13.2). In Thailand, the minimum live load on the roof stipulated in the Building Control Act B.E. 2522 or

the Building Control Regulations B.E. 2544 issued by Bangkok Metropolitan Administration is 100 kilograms/square meter. This limits the use of the roof as a roof garden (Figure 13.1).

4. Noise filtration by 40 dB. It is widely known that trees can filter sound. The classic example is Freeway Park in Seattle, U.S.A. The roof of the building next to the freeway is turned into a park; therefore, only some of the traffic noise can reach the building. Moreover, trees can filter pollutants.

5. Air and water purification and rain harvesting

6. Energy efficiency. Trees can keep the temperature in the building low without the use of air conditioners.

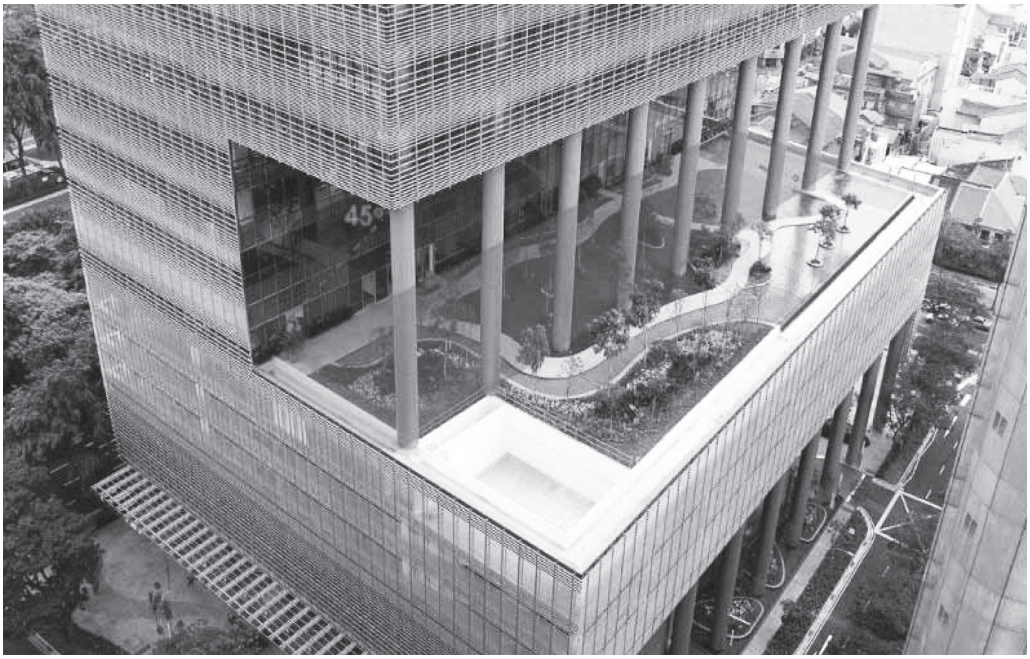
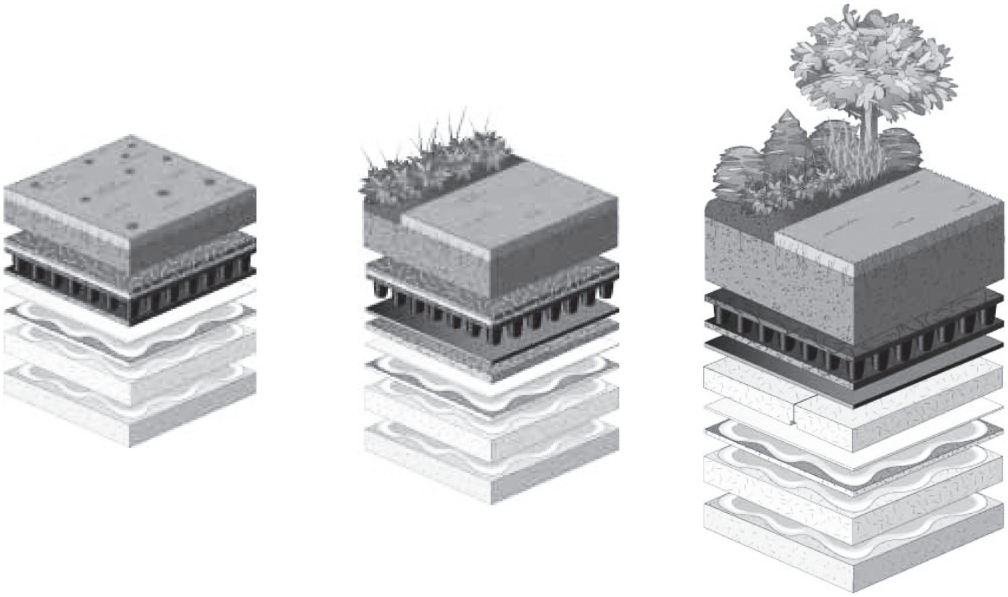


Figure 13.1 *The outdoor refreshment areas policy (ORAs) of Singapore*



Source: *www.carlisleroofgardens.com*

Figure 13.2 *Components of the roof garden that can harvest rain water*

Figure 13.3 *The roof garden in the Sentul Project in Kuala Lumpur designed by Seksan*

13.3 Components of the roof garden

The roof garden consists of (Figure 13.2):

- A sub-grade
- Protection fabric
- Insulation
- Drain boxes/drainage composite/drainage cells
- Edging/root barriers
- Growth media/pavement/ground cover materials
- Other structures/furniture

13.4 Issues to be considered when designing the roof garden

The designer has to work with the architect and the engineer in the following aspects:

- Structure/load, especially the weight of the growth media of a big tree and a pool. The load of the growth media (soil) and a pool can be roughly calculated as the volume of 1 cubic meter equals 1 ton/square meter of concentrated load on the roof.
- Wind is usually stronger at a higher altitude so sometimes it poses difficulty in designing the garden and the choice of plants because some plants cannot withstand strong winds.
- Drainage and leakage protection
- Characteristics of plants: soil, root systems, wind resistance
- Position of skylight/ventilation
- Climate: moisture and heat
- Accessibility/maintenance/function
- Containers can be divided into three types depending on the growth media.

Figure 13.4 *The roof garden that can harvest rain water in the Oasis 21 Project, Nagoya*

Figure 13.5 *The green roof of a building in Ewha Women's University in Seoul, Korea designed by French architect Dominique Perrault*

Shallow assembly: The depth is between 6.5 and 10 centimeters.

Medium assembly: The depth is between 12 and 20 centimeters.

Deep assembly: The depth is more than 20 centimeters.

The roof garden can be used as a rain garden/rain water harvesting, urban agriculture in addition to adding a green area in the city.

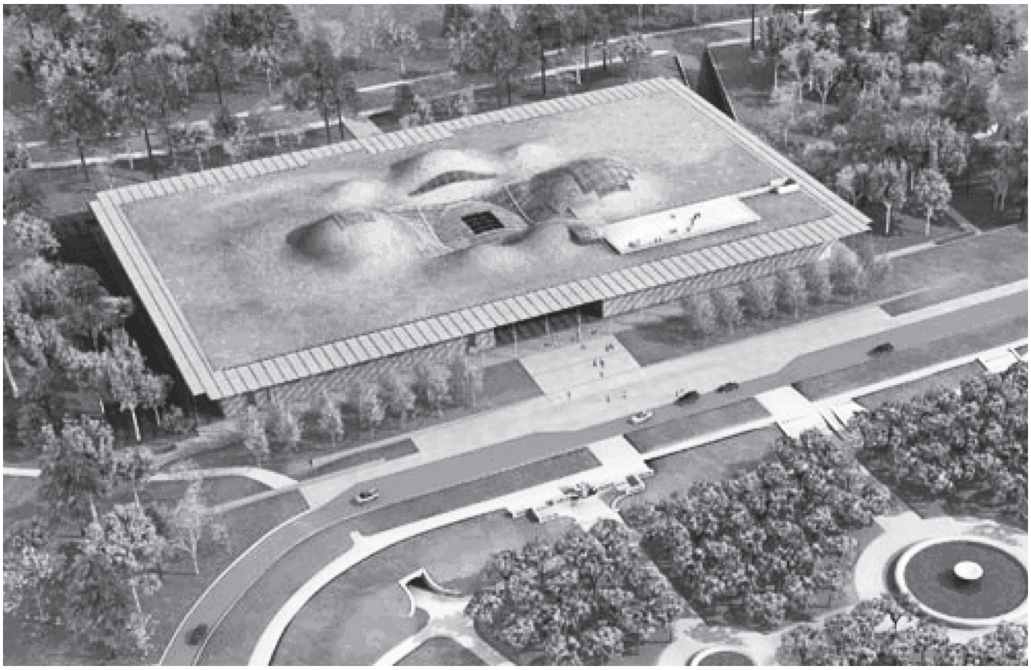


Figure 13.6 *The green roof in Rana Creek Living Architecture Projects: California Academy of Science*

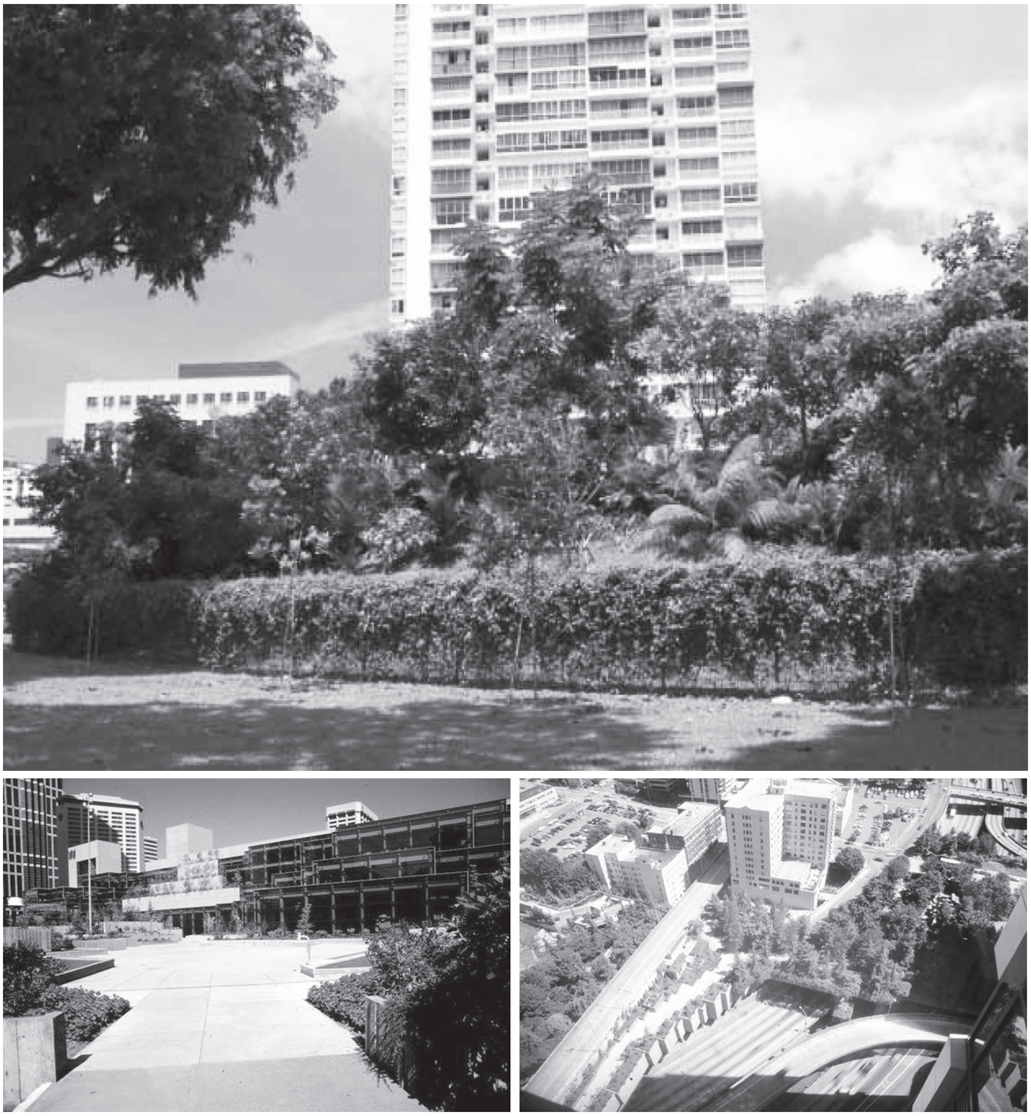


Figure 13.7 *A parking lot project built under the green roof in Singapore and Freeway Park in Seattle*

Figure 13.8 *The green roof concept is applied to the design of a parking lot of a condominium (top left), a building in the National University of Seoul and a restaurant at Garden by the Bay, Singapore (bottom)*

The vertical green area on the exterior wall of Mitsubishi Pavilion in the World Exposition in Aichi

Chapter 14

Green Design Concepts

14.1 Preface

Since Thailand is in a hot spot for drought, floods and cyclones (The Climate Game Change, Bangkok 22 January, 2009), many measures have been taken including the sufficiency economy philosophy proposed by His Majesty the King and this is well-recognized by the United Nations as a way of sustainable development. The world also faces the greenhouse effect. The government and the private sector have launched many environmental projects such as the green label, the green building and the introduction of building design criteria such as LEED or BREEM as well as the afforestation campaign, Earth Day (April 22), and Car-free Day.

As mentioned in Unit 13, the roof garden and the green roof in Singapore are interesting examples in terms of policy and laws such as Landscape for Urban Spaces and High-Rises (LUSH), which can increase the green area by 100% of the original site.

The Japanese people are environmentally conscious as seen from the 2005 World Exposition in Aichi. The green wall was introduced and designs for protection of environment and forest areas were systematically carried out. The Sanshiro pond in Tokyo University, Odaiba project and the Millennium Forest are examples of such awareness.

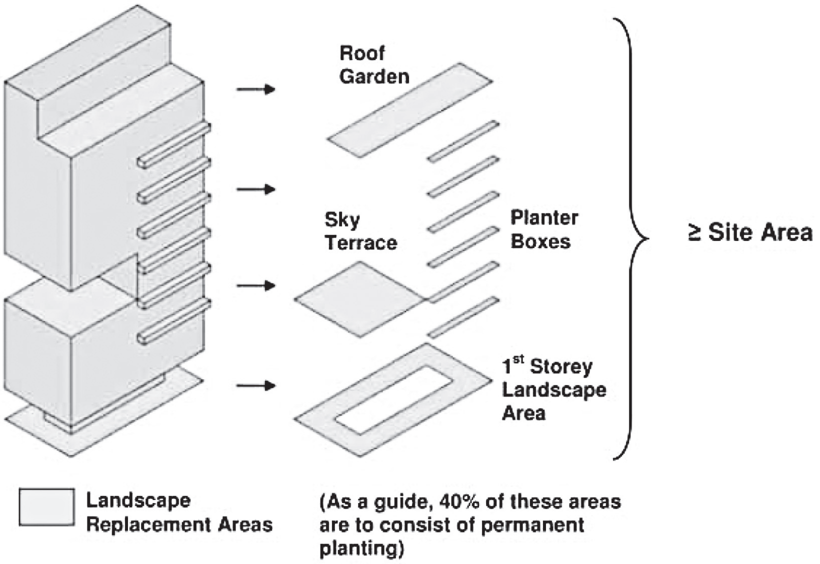


Figure 14.1 *The LUSH policy to increase the green areas in Singapore by 100% of the original project site*

Malaysia has introduced the Sentul project, a real estate development project in the center of Kuala Lumpur. A big green area is set aside and a large roof garden (green roof) is provided so this project offers a pleasant atmosphere for the city.

Korea has many distinctive green projects such as the Cheonggyecheon development project that removed the expressway that ran through Seoul and the Seonyodu project that turned the wastewater treatment plant into a public park exhibiting plants that can treat wastewater. Another project is Dongdaemun

Figure 14.2 *The vertical green area on the exterior wall of Mitsubishi Pavilion in the World Exposition in Aichi*

Figure 14.3 *Details about the construction of the vertical garden and the drip irrigation on the exterior wall of the Japanese Pavilion in the World Exposition in Aichi*

Design Plaza and Park (DDPP) – a green building that integrates sustainable development. The project designed by Zaha Hadid takes social, environmental and economic aspects into consideration.

As for China, the Olympic Forest Park in the heart of Beijing is another example of green design. This is an urban forest, a wastewater treatment site, an urban air purifier and home to many plants and animals.

14.2 Roles of landscape architects in green architecture

For green architecture, problem analysis has to be carried out. The problems include the urban heat island effects, dust, noise and pollutants. Effective ways to use the land so that it can yield the most benefits have been sought. For example, the afforestation project, the recycling of wastewater, the growth of leafy plants so that they can release more oxygen and the growth of plants suitable for the water supply and the ecology. Plus, the effective use of natural resources and energy, the recycling of some materials and concerns about the biodiversity of plants and animals are also taken into consideration.

Figure 14.4 *The architecture and designs for the environment of the Sentul Project, Malaysia*

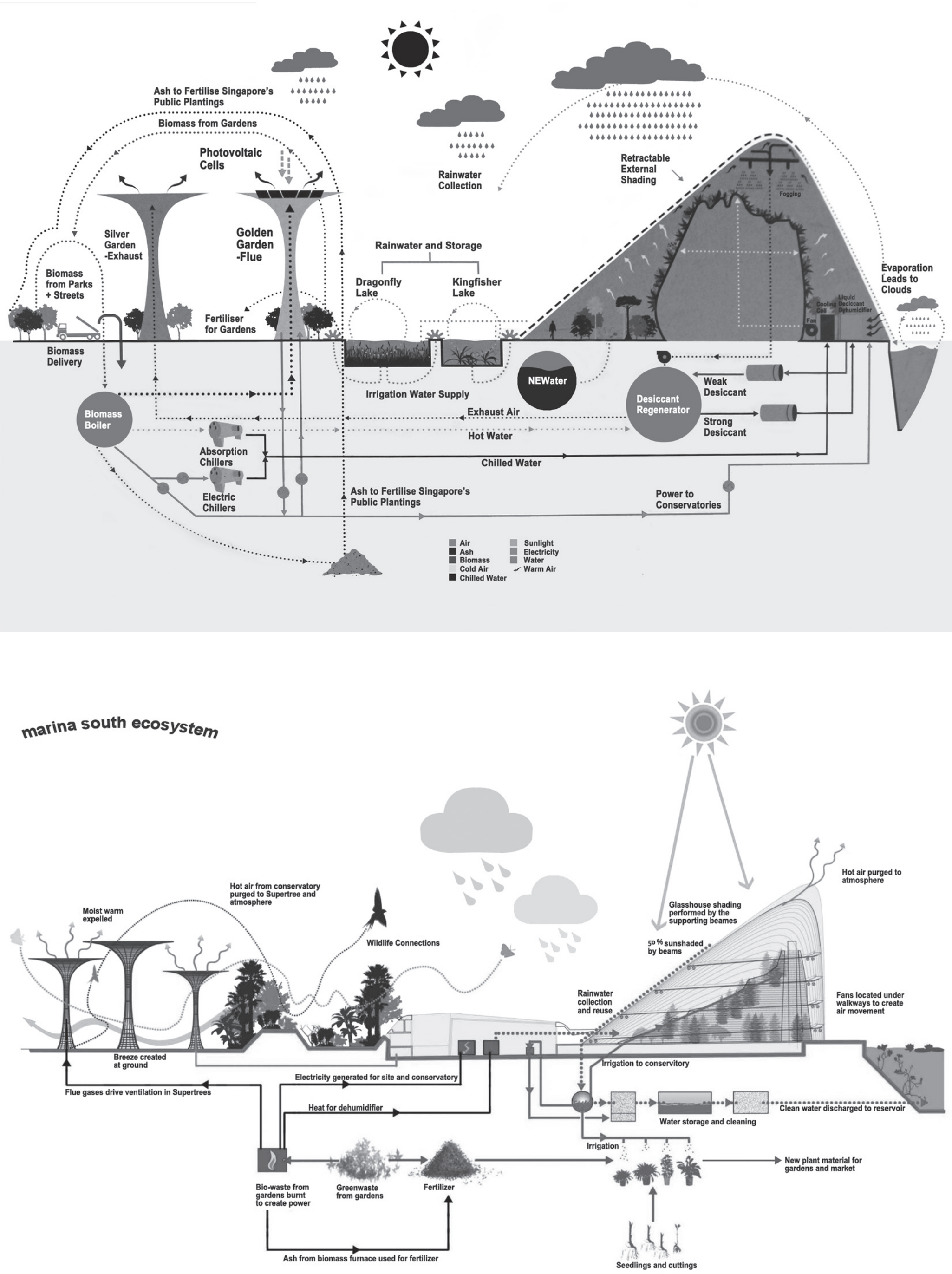


Figure 14.5 *The architecture and designs for environment of the Garden by the Bay Project, Singapore designed by Grant Associates*

Figure 14.6 *The outdoor refreshment areas policy (ORAs) of Singapore and The Millennium Forest*

Figure 14.7 *Singapore Barrage, a model for water management*

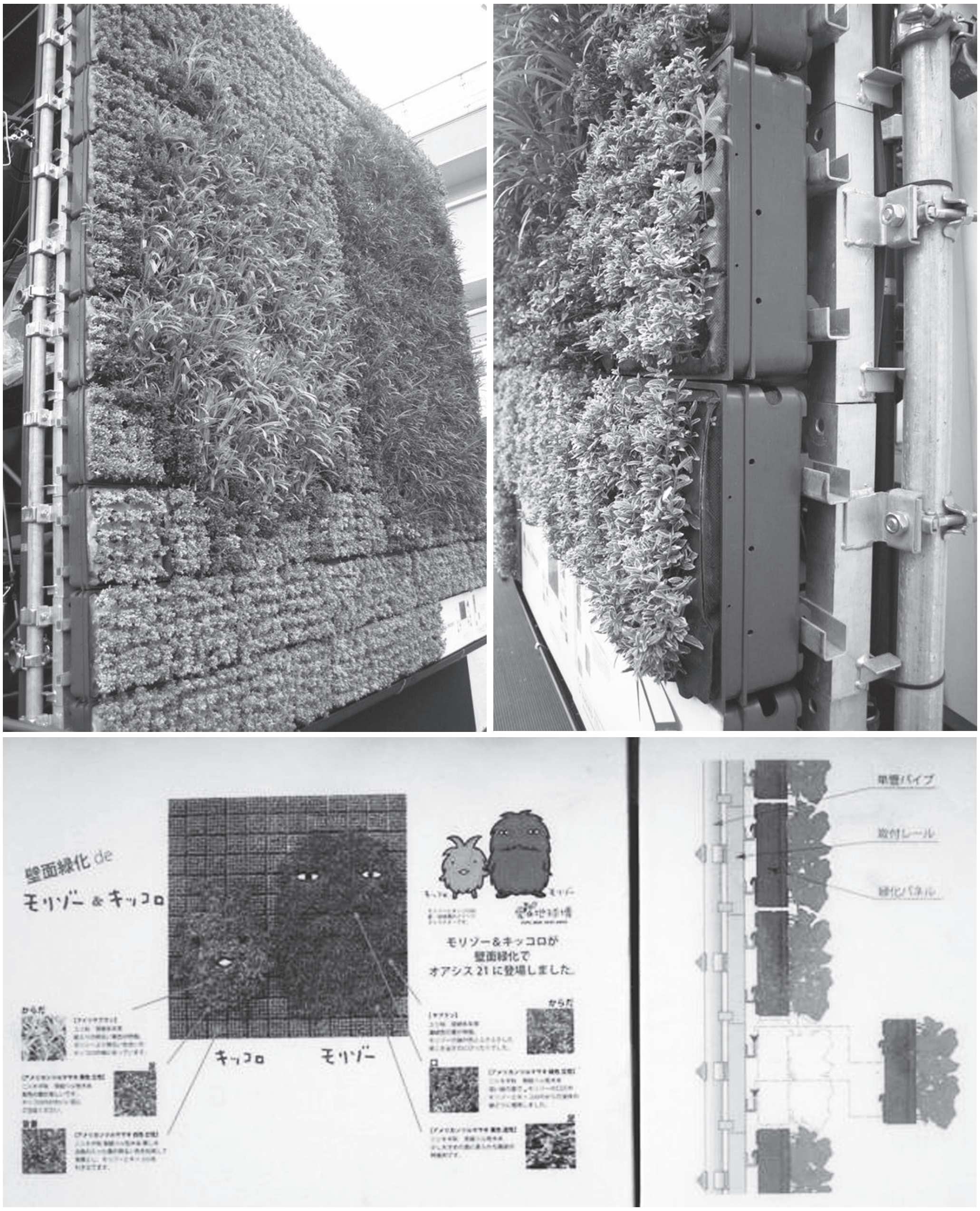


Figure 14.8 *A vertical garden and its construction details*

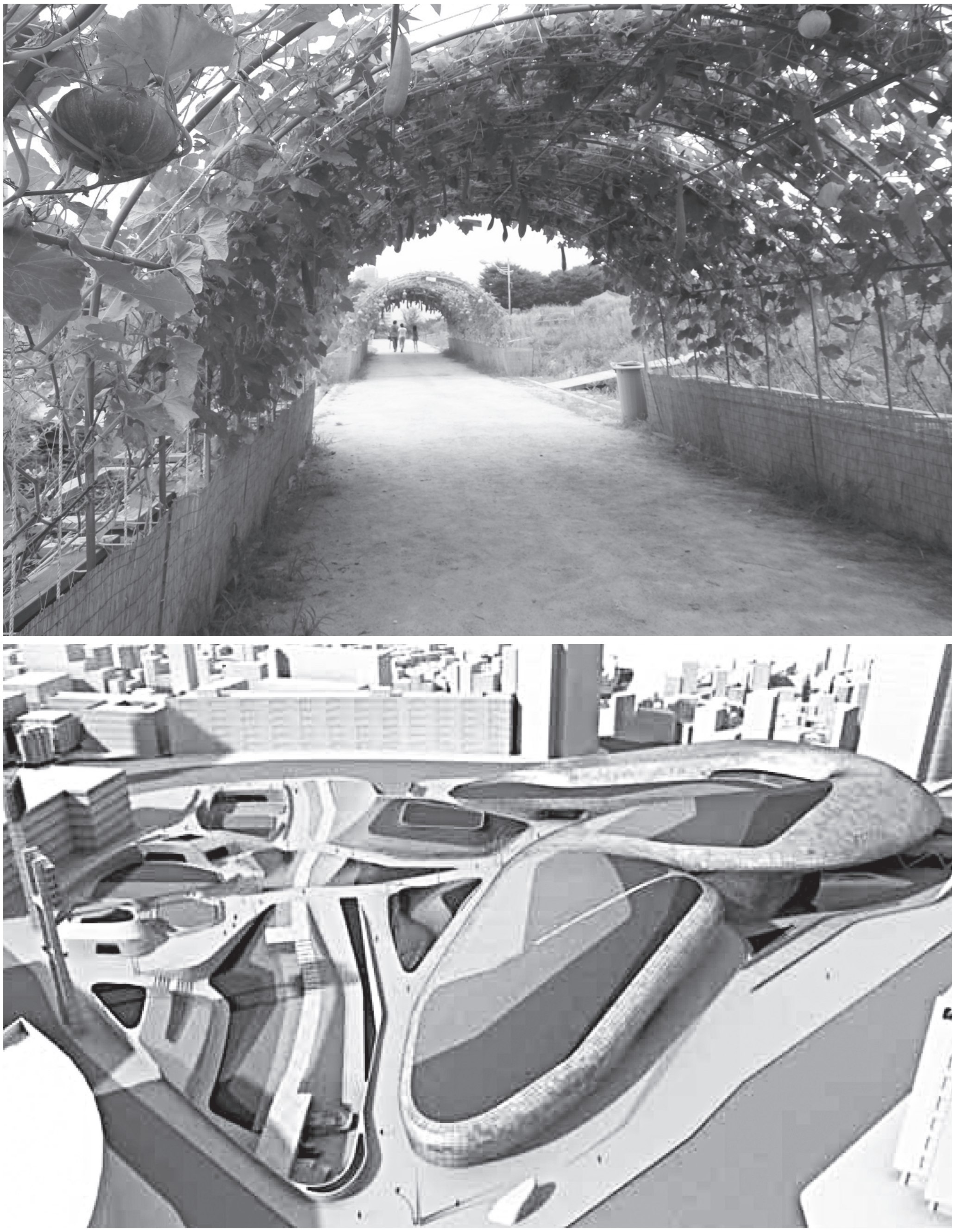


Figure 14.9 *Projects applying green architecture such as urban agriculture and Dongdaeun Design Plaza, which integrates the concepts of sustainable development*

At present, cities face many environmental problems so the case study in this chapter is the design of the Olympic Forest Park designed by Herzog & de Meuron Company from Switzerland and Ai Weiwei, a consulting sculptor. The Bird nest stadium can hold 91,000 spectators. There are 80,000 permanent seats and 11,000 extra seats. This architecture combines an advanced technology and more than 42,000 tons of iron was used to build the stadium so how can this be called a green project?

The water cube sport center was designed by PTW and Ove Arup and Teflon is used as the structure and solar energy is harnessed to power the wastewater filter system. The water to be added in the pool is kept in a large reservoir under the ground. Moreover, to make the walls of the water cube look like water, the technology obtained from a study of a physicist at Dublin Trinity College is used. The walls look like a live sponge and the pool can resist an earthquake.

The International Federation of Landscape Architects (IFLA), the German Development Cooperation, Mr. Achim Steiner, the UN Undersecretary General Executive Director of the UNEP, the Greenpeace and the Environmental Performance have recognized the park in many categories: promotion of landscape architecture, sustainable development, wastewater and waste management, effective use of energy and waste management respectively. It also won the 2007 Torsanlorenzuo International Prize in Landscape Design and Protection (Section: Urban Green Space) and the President's Award in 2008 IFLA Landscape Planning Category. As a result, this project is interesting in terms of planning, sustainable development and lifelong learning resources in environmental aspects such as alternative energy and green concepts. It can inspire the young generation of landscape architects to create works that are environmentally friendly and sustainable.

14.3 Landscape architecture and green architecture

According to LEED, green architecture focuses on:

1. Sustainable sites (SS)
2. Locations & linkages (LL)
3. Water efficiency (WE)
4. Energy & atmosphere (EA)
5. Awareness & education (AE)
6. Material & resources (MR)
7. Indoor environmental quality (IEQ)

The first three aspects are related to landscape architectural design and the principles of landscape architectural design mentioned in this book are very helpful in green architecture. The principles include roof landscape design, interior landscape design, designs to reduce impervious areas, natural wastewater treatment systems, soil improvement, water source development, roof gardens that harvest rain water, urban agriculture concepts and royal initiative projects.

14.4 Trends in green architectural technology and construction techniques

Current projects are geared towards green architecture and some have integrated the three elements of sustainable development – economy, society and environment, such as Dongdaemun Design Plaza (DDP) in Seoul, Cheonggyecheon project and the Seonyudo Park project.

There are many projects that make us aware that the quality of life and environment are key to sustainable development and more realistic as a the solution to environmental problems is than the invention of machines which consume energy word fully. In this chapter, the writer would like to present

Figure 14.10 The Olympic Forest Park plan (Jie Hu, 2008)

a case study related to landscape architecture concerning environmental awareness – the Olympic Forest Park.

14.5 The Olympic Forest Park

This is the biggest square park in Beijing (Hu, Wu and Lu, 2008) covering an area of 4,250 rai divided into 2 phases by the 5th ring road. The northern part covers an area of 1,875 rai and the southern part covers an area of 2,375 rai. The northern part is near Biyu Park and the southern part is near the sports terrain and the stadium running through the 4^{th} ring road toward Tiananmen Square.

The head of landscape architecture, Hu Jie from the Planning & Design Branch of Landscape Architecture, Beijing Tsinghua Urban Planning & Design Institute, integrated Feng Shui into green infrastructure to make this park a green lung. The Olympic Forest Park can be divided into:

1. The main mountain
2. The water
3. The celestial world
4. The center of heaven
5. Finding pleasure in a forest stream
6. Wetland flower terraces

In addition to serving the competitions during the Olympic Games, it is intended to be a park afterword. The integration of culture, ecology and technology of this park can be considered sustainable development. The landscape architects and the engineers in this project prioritized environmental conservation, traditional Chinese culture and biodiversity.

The northern part of the park – which is more difficult to access – is designed to be a forest where trees and rare species of animals are found and there is an ecological corridor for these trees so animals can move to the southern part.

Both Chinese and foreign companies had to work together to finish this large project in time for the Olympic Games. They had to agree on major planning such as the soundscape and traffic noise control analysis, the emergency use diagram: human and wildlife, the ecological diversity analysis and planting design diagram. The green area covering an area of more than 450 hectare is home to more than 530,000 trees, more than 60 species of shrubs, and more than 80 species of ground cover plants. Other major plans included the plants in different seasons, the distribution of overpasses, the non-polluting battery-powered bus line diagram and the emergency use diagram – a fire escape plan. Technologies are used in the following sub-projects:

1. The most advanced water simulation and maintenance system focusing on the recycling of water used in the park
2. An exhibition green house of water quality ecological purification and the maintenance technology of adding water focusing on treating wastewater so that it can be recycled
3. Rain and flood recovery and utilization system with a utilization ratio of 95%
4. A resource recovery system of solid wastes
5. Zero sewage drainage in the park. It is estimated that:
   - There will be 5,300,000 visitors per year.
   - There are 4,280 people working for the park.
   - The amount of wastewater to be drained is 86,400 cubic meters per year.
   - The sewage drainage system has to discharge 1,590.91 cubic meters a day.

The following are wastewater treatment technologies:

1. Membrane bioreactors (MB)
2. Fast bio-degradation treatment (FBT)
3. Bio-degradation of dejection treatment (BDT)

6. LED Shi Xian Li Bai's poem: Lunar Platform

7. An ecological corridor straddling the super highway for the relocation of wildlife

8. Ecological research: Contribution of the forest park as urban forest to Beijing. It is estimated that:

- 5,400 tons of oxygen will be released each year.
- 7,200 tons of carbon dioxide will be absorbed.
- 32 tons of sulfur dioxide will be absorbed.
- 4,905 tons of dust will be trapped.
- 67.5 cubic meters of water is needed each year.
- The moisture in the forest will be higher than other areas by 27%.
- The temperature in the forest will be cooler by 3-5°C in the summer and higher by 2-4°C in the winter.

9. A swift pagoda bird tower

10. The soundscape plan of the forest park

11. A solar photovoltaic station: A megawatt-class program of photovoltaic panels

12. Green energy vs. ecological energy saving buildings design: A geothermal pump system

Figure 14.11 A landscape architectural design adopting the idea of the wastewater natural treatment system used in the Olympic Forest Park

Bibliography

A consideration of Community Wastewater Characteristic and Influent quantity in Thailand. **The Documentation of Environmental Engineering Association of Thailand Conference 36**. Environmental Engineering Association of Thailand. 1993. [In Thai]

Ariya Arunintra. 2000. **The Efficient Development of Urban Open space Network and Vacant Land Concept; Case Study of Paris**. Faculty of Architecture Journal. [In Thai]

Ariya Arunintra. 2006. **Memorial Park: The Commemorative Landscape**. [In Thai]

Ariya Arunintra. **Spatial Landscape and Project Management**. Faculty of Architecture Journal. 1997. [In Thai]

Ariya Arunintra. **The Axis to Nature: The Ecological Design and Planning of Beijing Olympic Forest Park**. Urban and Regional Planning Conference paper. 2008. [In Thai]

Austroads. 2009. **Guide to Road Design Part 3: Geometric Design**. Beardsley, J. Earthworks and Beyond.

Code for Sustainable Buildings. **UK Green Building Council**. http://www.ukgbc.org/resources/publication/uk-gbc-task-group-report-code-sustainable buildings.

Construction sector rises to challenge of building eco-friendly homes of the future. **The Guardian**. Wednesday 28 February 2007. http://www.theguardian.com/business/2007/feb/28/communities.society.

Decha Boonkham. 2009. **Site and Landscape Planning**. [In Thai]

Department of Public Works and Town & Country Planning. Ministry of Interior. 2009. **Project Management and Levee Construction Technology**. [In Thai]

Earth Day. http://www.earthday.org/

Elwood D. Brickford and Stuart Dunn. **Lighting for the Plant Growth**.

Faculty of Architecture Journal. Electrical Online Documentaries. www.nectec.or.th/courseware/electrical. [In Thai]

FHWA (the Federal Highway Administration) U.S. Department of Transportation. 2009. **Speed Concepts: Informational Guide**.

http://www.carlisleroofgardens.com/

http://www.nvtl.nl/download/ifl a200706.pdf [Online] Menzies, Diane. **Benchmark for a Green Olympics**. IFLA, 2007. IFLA Newsletter #71 June 2007.

http://www.sydneyolympicpark.com.au/_data/assets/pdf_file/0020/839/olympics_australia_managing_monitoring_remediated_land.pdf [Online] Laginestra, Edwina and Hughes, Kate. 200x. **The Olympic in Australia: Managing and Monitoring Remediated Lands**. Olympic Coordination Authority, NSW, Australia.

Hu Jie, Wu Yi-xia, and Lu Lu-shan. 2008. **Analysis & Planning: The Beijing Olympic Forest Park**. Selected Papers of Chinese Landscape Architecture. Chinese Landscape Architecture Magazine.

Hu Jie. 2008. **Sustainable Practice in China: The Olympic Forest Park**. Beijing. Booklet from 2008 ASLA Annual Meeting & EXPO: The Premier Event for Landscape Architecture Professionals.

Indian society of lighting engineers (ISLE) Online Documentaries. **Electrical Knowledge and Illumination**. www.tieathai.org. [In Thai]

Irrigation Tutorial. http://www.irrigationtutorials.com

Kiatisak Chantra. **Introduction to the Levee Construction**. Town and Country Development Bureau. Department of Public Works and Town & Country Planning. [In Thai]

Landphair, Harlow C. 1979. **Landscape Architecture Construction**. New York: Elsevier North Holland, Inc.

Nelson Hammer. **Interior Landscape Design.**

Process: Architecture 40, Dialogue With Nature. Process Architecture Pub. Co. Ltd. (August 1, 1983)

Professor Norman W. Garrick. Geometric Design of Transportation Facilities AASHTO Handout. 2004. **A Policy on Geometric Design of Highways and Streets**.

Sathian Charoenrien. **Landscape Construction II Handout Lecture. Drainage System**. [In Thai]

Stephen Sorivens. **Interior Planting in Large Building**.

Target Zero. **Forks North Portage Corporation**. http://www.theforks.com/target-zero

Untermann, Richard K. **Grade Easy**. 1973. Landscape Architecture Foundation, Inc. Virginia.

Untermann, Richard K. **Principles and Practices of Grading, Drainage and Road Alignment: An Ecologic Approach**. Englewood Cliffs, New Jersey: A Reston Book, Prentice-Hall, Inc.

URA Singapore Circulars. 2009. http://www.ura.gov.sg/circulars/text/dc09-09.htm

Urban Planning & Design Institute of Tsinghua University (UPDI). 2007. **The Collection of Papers on Beijing Olympic Forest Park**. For 2007 China Landscape Architecture Summit: A New Highlight in Landscape.

Water Quality Management. Pollution Control Department. www.pcdv1.pcd.go.th/WaterQuality/WasteWT/menu.html [In Thai]

Williams, **George. Grading: A Workbook of Manual Land Grading Techniques**. Landscape Construction Note Handout (712-Landscape Design). Revised Edition. University of Canberra, Australia.

Xeriscape: Landscape Water Conservation Agricultural Communications. The Texas A & M University System.

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The author graduated her first degree from Department of Landscape Architecture, Chulalongkorn University; the best-known institution in Thailand. Then she practiced as a landscape architect for a year and was employed as a project landscape architect in Suan Luang Rama IX King Park Foundation. In 1987, she went studying abroad for the higher education in the US at Department of Landscape Architecture, University of Colorado at Denver. She spent another one year being an intern at a firm named Design Workshop, Inc. In 1989, she went back to Thailand to work at Public Works Department. Her works involved park design and large scale planning. Her most outstanding project is Queen Suriyothai Memorial Park.

Her turning point in 1994, she received the IHS commendation award, whilst during the economic bloom, she was transferred to a lecturer position at Department of Landscape Architecture, Faculty of Architecture, Chulalongkorn University. In 2001, she decided to shift her career to the more research based by pursuing her PhD at AIT. Her PhD dissertation was awarded an outstanding research prize from NRCT – The National Research Council of Thailand. She is also a former deputy director of Chulalongkorn University, Social Research Institute – CUSRI. Her research interests are urban landscape and urban environmental management.Aruninta was granted many international fellowships included JICA (Japan), the Netherlands Government Fellowship, Fulbright (USA), Science-Po (France).

In 2007, Dr. Aruninta has been appointed by the Prime Minister of Thailand to be one of the five honorable board members of Thailand's Council of Architects (2007-2009) and served the National level Committees. She has represented Thailand as IFLA (International Federation of Landscape Architects) council and hosted 2011 IFLA APR Congress in Bangkok, Thailand.

Dr. Aruninta devotes her expertise in 'Green and Social Approaches' and also has been participated frequently in several forums, workshops, seminars, symposium, international conferences, exchanged programs. Dr. Aruninta has also published many articles in academic journals, magazines, blogs/online articles, and books in Thai and English. She has been a public contributor and shown up in TV/Radio programs on urban and environment issues.