Gautami Eco Park, Nepal

Bishal Raj Khanal 2018

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I would like to thank my family for believing me and letting me pursue my interest.

And, the landscape that has made living possible.

Bishal Raj Khanal, 2018

Abstract

The thesis presents a potential model of an Eco Park that would be suitable for the southern region in Nepal known as the 'Terai'. Several techniques of infrastructural interventions that can be made to sustainably create a functional landscape has been studied. The analysis of these techniques suggests how these various infrastructures can be incorporated into the design. This exploration results in a design which attempts to create an ecologically viable landscape which offers glimpses of the local historic cultural setting, which is replicable and would help to achieve sustainability.

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Introduction

Gautami Eco Park

The proposed site of this Eco park is located along the banks of the river Danda in Siddharthanagar, Nepal. Siddharthanagar lies in the southwestern terai region of Nepal. The city got its name from Prince Siddhartha, also known as Gautam Buddha, who was born there. Prince Siddhartha's mother Mayadevi died soon after his birth and Mahapajapati 'Gautami' was the maternal aunt who adopted baby Siddhartha and raised him.

Siddharthanagar is also a major port of entry via land from India into Nepal and the majority of imported goods and thousands of tourists enter Nepal via this port. The river Danda flows approximately a kilometer away from this major port of entry. The Gautami Eco Park and a stretch of a clean river Danda will reflect on the historic, cultural and natural aspect of Siddharthanagar as it greets visitors to Nepal.

Recently after Nepal transformed into a federal system, Siddharthanagar was recognized as a major city in western Nepal. One of the biggest national highways has been constructed there, the only other international airport in Nepal, besides the one in the capital city Kathmandu, is soon to be constructed and city planning efforts are being made to direct the urbanization in this city. Siddharthanagar is one of the most fertile and water abundant places in Nepal. It was largely dedicated to agriculture, but now that the physical infrastructural growth has begun in Siddharthanagar, these agricultural fields are being rapidly converted to accommodate housing and commercial functions. Urbanization has almost always brought along with it environmental degradation in Nepal. The capital city Kathmandu has become a concrete jungle where very little natural ecology exists; even trees are a rare sight. Gautami Eco-park will be a symbolic landscape to remind people of the significance of the natural ecological setting of Siddharthanagar and also provide refuge to some animals whose habitat has been encroached and existence threatened.

A bank of the Danda river that once functioned as a natural wetland, but now has been disturbed and altered, is the site for the proposed Eco Park. This Eco Park will explore ways of treating wastewater in small decentralized systems before the water actually enters the river, with the goal to provide a solution to the river pollution scenario in urbanizing Nepal. This Eco Park will also conserve and promote the habitat -supporting features of the site. And, will function as a living laboratory for the educational institutions that surround the site.

Background and Significance

Human settlements have always centered around a reliable source of water and most of the time around rivers. With industrialization, cities began to grow faster than ever exerting greater pressure on the water systems. In the early days of industrialization, the volume of waste accumulated in rivers was low and thus the rivers cleaned themselves through various natural processes. The dumping of a larger volume of untreated waste directly into the river reduces the self-cleaning ability of a river.

Nepal has approximately 6000 rivers which include rivulets and tributaries as a part of the Ganges basin. It is estimated that about 70% of dry season flow and 40% of the annual flow in the Ganga River is contributed by the rivers flowing through Nepal (SOW, 2018). The Ganges basin is the world's most populated river basin (WP, 2018).

Urbanization, like in the rest of the world, has exerted pressure on rivers in Nepal and have impaired their value for both human use and environmental services. Fecal sludge, wastewater, and various other sewage empty into the rivers untreated. Large-scale filtration plants were established but failed. Small decentralized treatment systems could be a possible solution to treat the wastewater before it enters the river. The accumulation of industrial grade chemicals has wiped away many aquatic lifeforms and has severely polluted the waters.

Every year during the monsoon, instances of severe flooding are reported in Nepal, however, not much has been done in terms of developing a long-term flood mitigation program. In the capital city Kathmandu, heavy concrete embankments are being installed in the name of river bank protection, which has caused an alteration of river morphology and altered the sediment regime, adversely affecting the plant and animal communities. The rest of the country is likely to follow the trend and ruin the riverscape and diverse biotic systems that a river supports unless a better way of flood control is introduced.

The southern plain of Nepal is referred to as the Terai belt where the rivers deposit rich alluvial soil. The Terai region is incredibly rich in terms of its biological diversity. It is endowed with a variety of flora and fauna; it also has a large range of insect species and aquatic life. These plains and their wetlands provide breeding grounds for many species of migratory birds that come here every winter from as far as Serbia when the northern hemisphere freezes. This region is also equally favorable for human settlement; the cities are expanding at a rapid pace. The pollution in rivers is also causing habitat loss and thus endangering many species in Terai. It is important to generate awareness in the general public about the importance of freshwater and related ecology to conserve the environment.

In this context, this study proposes a model of landscape architectural design, as Eco Park, which will explore the various methods of treating the wastewater, bank stabilization, conserving habitat and educating people about the beauty of freshwater ecology.

Methods

An Eco Park is a relatively new concept and has not been introduced in Nepal. Several examples of Eco Parks in the United States, Canada and many other parts around the world served as an inspiration for this project. The exploration progressed with findings of the philosophy of Eco Parks, in both concept and design. Crissy Field in the USA, The Fishtrap Creek Nature Park in Canada, Xochimilco Ecological Park in Mexico are few of the best examples of eco parks.

Various design techniques of environmental reclamation were investigated. In particular, the project focused on 5 primary criteria, namely wastewater treatment, bank stabilization, habitat conservation, education, and recreation.

Various examples and design techniques were studied and synthesized. Based on the literature review, design criteria were developed for the design of the Eco Park.

The data gathered from the Nepal Study Center at the University of New Mexico (UNM) served as a means of determining the various level of pollutants present in the Danda river. Student Volunteers from UNM collected this data.

GIS data provided by the Ministry of Urban Development in Nepal served as a means to determine the various aspects of topography, land use, road networks and building footprints. Besides the GIS data, pictures and anecdotal evidence were gathered to determine the occurrence of the flood, depth of the water and waste accumulation. The GIS topo lines were interpolated further based on aerial imagery of the site.

Various sources in the literature provided information about designing wetland remediation for incoming pollution, bank stabilization, habitat conservation and the educational aspect of an Eco Park. The process of exploring possible strategies for restoring the Danda River began with a search for small-scale measures which stand out for their practical and economical applicability. The aim of the study is finding solutions which can be applicable in solving ecological problems beyond the site boundaries.

Literature Review

This study hopes to find a solution that is practical for use, low cost, ecologically sound. And hence is sustainable for use in Siddharthanagar, Nepal. The literature review will focus on 4 of the 5 criteria set for the development of the Eco Park, namely wastewater treatment, bank stabilization, habitat conservation and, education. The synthesis of literature will determine how the various techniques and theoretical underpinnings in the literature can be best used in the design project.

The sources of the literature review include books, journal article, reports, and websites.

Wastewater Treatment

Wetlands

Wetlands are natural filters of wastewater, highly efficient and, support many diverse species. Wetlands are regarded as the most productive landscapes because of the biodiversity they support. Wetlands hold and recycle the nutrients that are brought along with the flood. These nutrients in turn support macro- and microscopic vegetation which makes it possible for the conversion of various inorganic chemicals into the organic biomass.

Wetlands may not remain wet throughout the year; they can dry out seasonally. Many wetlands form after the rain event or during the rainy season. Wetlands are the middle grounds that occur between land and water and are neither clearly terrestrial nor aquatic (Vymazal and Kropfelova, 2008). It is difficult to determine the edge of a wetland based on the dryness or wetness of the surface. Usually, wetlands are the areas that periodically grow hydrophytes or have wet areas that develop anaerobic conditions which limit the types of plants that can grow in such environments.

Freshwater marshes are mostly covered by herbaceous plants. Submerged and floating plants occur abundantly in most wetlands. Emergent plants are the distinguishing feature of a marsh that do not occur in other aquatic environments. Most prevalent emergent plants include cattails (Typha), bulrush (Scirpus), reed (Phragmites), grasses, and sedges (Carex) (Hammer, 1991). Places that are only occasionally flooded with shallow water once or a few different times a year can develop conditions which support marsh plants and thus could perform as a wetland.

Constructed Wetlands

Constructed Wetlands (CWs) is a low-cost, biological wastewater treatment technology that mimics the filtration processes that occur in natural wetlands. Substrate composition, vegetation type, and flow pattern can be well monitored and regulated in constructed wetlands making them suitable for the purposes of experiment. The operating mechanism of a constructed wetland is less complicated than an actual natural wetland. Constructed wetlands offer more advantages over natural wetlands some of which are site selection, flexibility in size, control over the hydraulic pathways and retention time (Brix, 1993).

The pollutants present in the water are generally removed by the following mechanism in constructed wetlands:

Suspended Solids
Sedimentation
Filtration

Soluble organics
Aerobic microbial degradation
Anaerobic microbial degradation

Phosphorous
Plant and microbial uptake

Nitrate
Conversion into ammonia by microbes
Microbial conversion to nitrogen gas
Plant uptake through roots

Ammonia
Converted into vapor, volatilization (Surface Flow system)
Metals
Sedimentation
Plant uptake through roots
Microbial degradation

Pathogens
Sedimentation
Filtration
Natural death
Predation
UV radiation (Surface Flow system)
Excretion of antibiotics from the roots of plants

Types of Constructed Wetlands

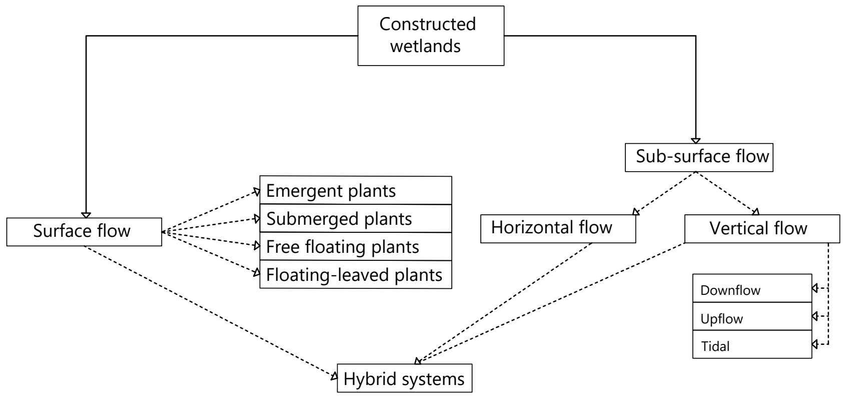

Figure 1: Classification of constructed wetlands for wastewater treatment (Vymazal, 2001)

Constructed wetlands are generally classified based on the nature of water flow and the types of macrophytic growth. A hybrid system combines both surface and subsurface flows. For the purpose of this study, we will focus on surface flow constructed wetlands.

The surface flow (SF) system has water flowing in a relatively shallower depth through the system and is relatively low cost when compared to subsurface flow systems. The shallow water depth, the lower velocity of water, the presence of plants and waste allow the system to operate correctly (Reed et al., 1988). One of the primary mechanisms by which the SF system operates is bringing the wastewater in contact with biological surfaces (Kadlec and Knight, 1996). The surface flow system is categorized into four groups based on the type of plants it employs.

A system with free-floating plants

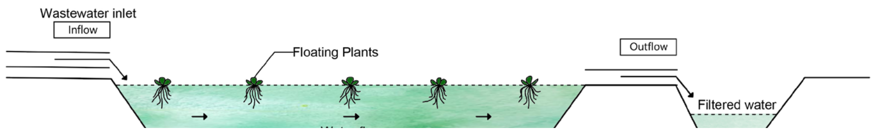

Figure 2: constructed wetland with free-floating plants, (adapted from Vymazal, 2001)

This system consists of one or more ponds. This system makes use of the plants that freely float on the surface of the water. The plants that can be used are diverse; they vary in form and habitat ranging from relatively bigger species such as water hyacinth to smaller varieties such as duckweed, which has few or no roots (Brix and Schierup,1989).

Microbial processes remove the organic waste contained in water. The root surface provides the area where the microbes attach. To allow microbes to function efficiently the water level and velocity have to be kept low. The plants on the surface attenuate wind induced turbulence allowing the sedimentation of suspended solids.

Nutrients in the water are removed in a relatively complex process. Nitrates are absorbed by the plant roots to make amino acids and ultimately be converted into protein. The nitrifying bacteria present in the water also help in nitrification process; they convert the nitrates into nitrogen gas or ammonia. This process is efficient when the plant cover is partially on the water surface. Dense plant cover generally reduces the dissolved oxygen in water (Rai and Munsi, 1979).

Phosphorus is reduced by microbial activity, absorption into clay or other organic matter. Phosphorus removal is effective when plants are harvested on a regular basis (DeBusk and Reddy,1987). The harvest is necessary because the decomposing plant matter releases phosphorus back into the water.(Reddy and Sacco, 1981).

A system with floating-leaved plants

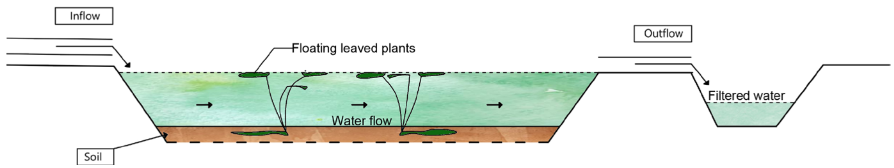

Figure 3: Constructed wetland with floating-leaved plants, (adapted from Vymazal, 2001)

Floating-leaved plants are rooted in the base of the wetlands while their leaves float on the water surface. Lotus and water lilies are the examples of the plants in this category. Constructed wetlands with floating-leaved plants are more successful in attenuating the force of the wind on water's surface which is likely to cause resuspension of the sediments (Vymazal and Kropfelova, 2008). Organic particles in the water undergo sedimentation and microbial degradation.

Nitrogen in the water is removed by volatilization (matter's state is converted into vapor) and by algae. The occurrence is algae is possible in the system with floating-leaved plants because the leaves partially cover the water surface. Nitrates are converted nitrogen gas.

Phosphorus is absorbed by plant roots. The decomposition of plant tissue releases back the phosphorus in water if not harvested regularly.

Nitrogen and phosphorus can both be absorbed by the plant roots and rhizomes. A study conducted by Twilley et al. (1977) showed that phosphorus can be absorbed also by submerged and floating leaves of Yellow Water-lily. However, this absorption is 10-20 times lower than that of the roots.

A system with submerged plants

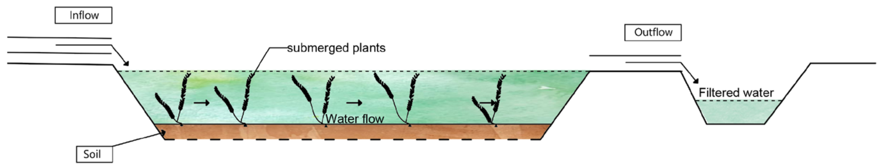

Figure 4: Constructed wetland with submerged plants, (adapted from Vymazal, 2001)

Submerged aquatic plants are attached to the ground below water and grow below water. These plants prefer oxygenated water and do not grow well in conditions where oxygen is low. Latge amounts of biodegradable organic content in the wastewater lowers the oxygen in water (Brix, 1993). A short term drop in oxygen level is not likely to harm submerged plant population. However, a long-term drop in oxygen levels may hamper the growth of submerged plants (Sahai and Sinha, 1976).

In addition to anaerobic conditions, other factors such as turbidity, sulfide and anaerobic sediments also discourage the growth of submerged plants (Best, 1982). High turbidity of the water prevents light transmission and as such cuts off the photosynthesis (Reed et al., 1988). According to Westlake (1981), increased turbidity may cause detectable changes in growth of the plants by 30% or more.

Studies have proved that although nutrients can be absorbed by the shoot, the major source of nutrients is absorbed by the roots. Carignan and Kalff (1980) reported that the sediments contributed to all the phosphorus absorbed by the plants. However, studies also prove that the nutrient content of the submerged plants is directly related to the nutrient levels in the water (Best, 1977). Ozimek and Renman (1996) suggest that the amount of nutrients absorbed from water and sediments varies widely among species.

A system with emergent plants

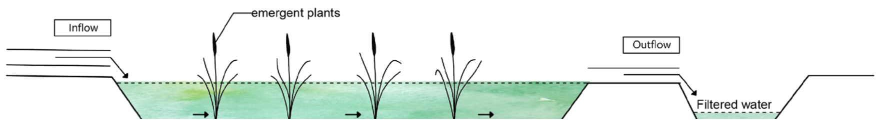

Figure 5: Constructed wetland with emergent plants, (adapted from Vymazal, 2001)

This system requires 20-30 cm of rooting soil, with a water depth of 20-40 cm. Emergent vegetation generally covers more than 50% of the surface.. Naturally occurring species co-exist with planted plants (Kadlec, 1994).

Some of the frequently used species of emergent plants in constructed wetlands are Phragmites australis (Common reed) Scirpus lacustris, Typha spp. (Cattail), Scirpus spp (Bulrush), Sagittaria latifolia (Arrowhead), Bolboschoenus (Scirpus), fluviatilis (Marsh clubrush), Eleocharis sphacelata (Tall spikerush), Scirpus tubernaemontani, Scirpus validus (Soft-stem bulrush) (Vymazal and Kropfelova, 2008).

The shallow depth, low velocity of water, and presence of the plants and particulate pollutants are required for the system to operate. The inflow of water containing particulate and dissolved pollutants is slowed down by the emergent vegetation and large area of shallow water (Kadlec and Knight, 1996). The processes that contribute the removal of pollutants are sedimentation, aggregation and surface adhesion (Merz, 2000). Wetland vegetation contributes to increased sedimentation by keeping the water relatively still.

Aggregation allows the particles to naturally form a cluster. The smallest of particles, such as suspended clay, do not usually settle within the detention time available in a wetland. Particles of this nature are removed by adhesion onto surfaces within the water. The places that allow these smaller suspended particles to attach are the emergent plants and the biofilms growing on the plant surface (Merz, 2000).

Nitrogen is removed in constructed wetlands by plant uptake and microbial action. Nitrifying bacteria in aerobic zones fix ammonia, and the nitrate is converted to free nitrogen in anoxic zones (zones which have reduced oxygen levels) by denitrifying bacteria. Plants and higher pH values favor ammonia loss. This system also removes phosphorus, but at a slower rate (Kadlec and Knight, 1996).

Wetlands develop favorable conditions for the removal of pathogens (disease-causing microbes). Physical filtration, UV radiation and sedimentation cause the removal of the pathogens. Chemical biocides excreted by wetland plants also kill these microbes. Predation by nematodes and protozoans, bacteria and virus, and natural die-offs are ways wetlands remove pathogens (Gersberg et al., 1989).

Floating mats of emergent Plants

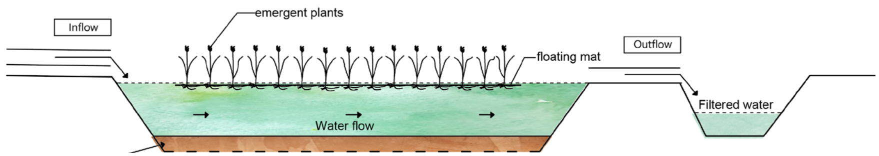

Figure 6: Constructed wetland with floating mat of emergent plants, (adapted from Vymazal, 2001)

In this system, emergent plants collected from a mature wetland are floated on the wastewater using various techniques to cover the wetland. No soil or sediment is required to be placed in the bottom of these mats. This system can effectively remove about 83% of the total nitrogen. Van Bruggen et al. (1994) found that floating Cyperus papyrus removed 81% of the nitrogen from a wetland.

Sizing

The sizing of the bed for constructed wetlands can be calculated using the formula devised by Kickuth. (UN-HABITAT, 2008)

Ah = {Qd (ln Ci – ln Ce)}/KBOD

Ah = Surface area of bed (m2)
Qd = average daily flow rate of sewage (m3/d)
Ci = influent BOD5 concentration (mg/l)
Ce = effluent BOD5 concentration (mg/l)
KBOD = rate constant (m/d)

KBOD is determined from the expression KTdn, where,
KT = K20 (1.06)(T-20)
K20 = rate constant at 20 C (d-1)
T = operational temperature of system (°C)
d = depth of water column (m)
n = porosity of the substrate medium (percentage expressed as fraction)

KBOD is a temperature dependent variable and the BOD degradation rate usually increases about 10 % per °C. Thus, the reaction rate constant for BOD degradation is expected to be higher in summer than winter. It has been found that the KBOD increases with the age of the system.

The example below shows typically how numbers can be plugged into the equation to calculate the area of the wetland.
Let us calculate the sizing of a constructed wetland for 400 individual outlets with a specific wastewater flow of 80 liters per outlet per day.

Average volume of wastewater (Q) = 400 x 80 / 1000 = 32 m3/d

To determine the influent BOD5 concentration, the wastewater sample should be analyzed in an accredited laboratory. In the absence of a laboratory, the concentration can be calculated as below:
BOD5 contribution = 40 g BOD5/pe.d
BOD5 concentration = 40 x 1000/80 = 500 mg/l
Let us assume that 30% BOD5 is removed by the primary treatment unit, then the influent BOD5 concentration to the wetland
(Ci) = 350 mg/l
Effluent BOD5 concentration (Ce) = 30 mg/l
KBOD = 0.15 m/d for HF wetland and 0.2 m/d for VF wetland
Substituting the values in the equation below:
Ah = {Qd (ln Ci – ln Ce)}/KBOD

Area for the wetland = 524.10 m2

Bed Configuration

The one-bed system is usually inefficient when the size of the treatment plant is large. It generates problems such as short-circuiting and inefficient water distribution. Better performance can be achieved by using two or more separate units that could be loaded separately. The cells can be combined in a parallel or series circuit.

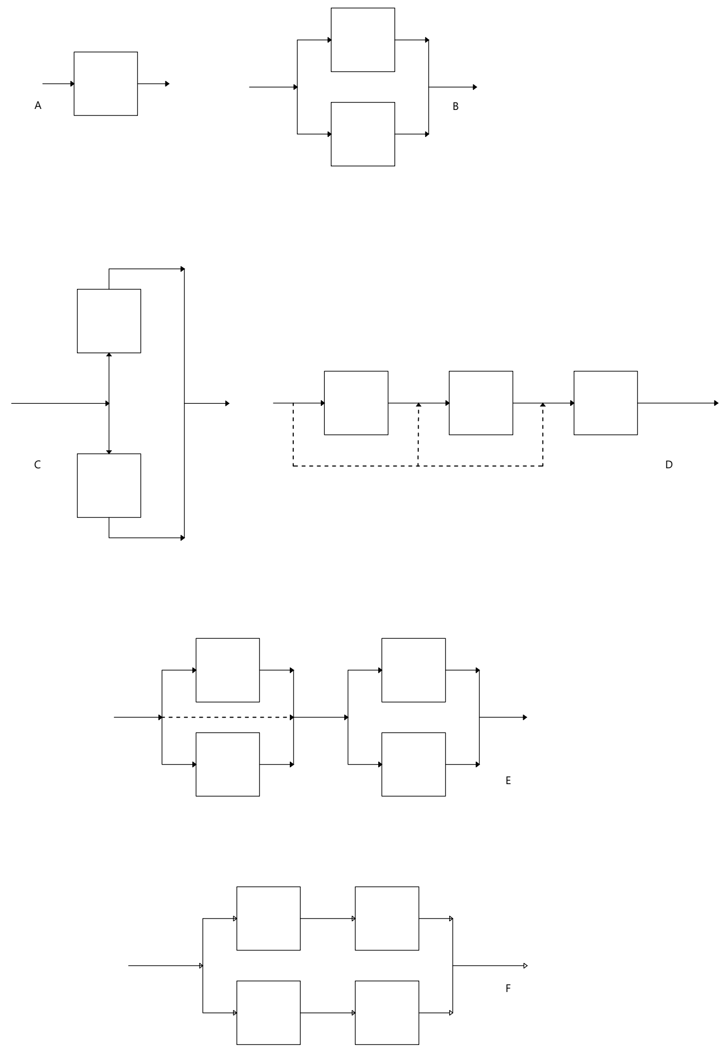

Figure 7: Various bed configuration in the constructed wetlands. A-single bed used for small systems, B, C-two parallel cells, D-beds in series with optimal step-loading or bypass, E-two parallel cells in series, F-two parallel series of cells. (adapted from Vymazal, 1998)

Bank Stabilization

Most rivers around the world have been subjected to human designed morphological alterations. Concrete vertical edges have limited the ever dynamic processes occurring in the rivers. As a consequence of this kind of intervention, the natural water filtration process and many ecological functions of a river system have been disrupted. The hydrological engineering of river canalization, building concrete embankments along rivers and water features are the maximum approach- the one that uses large amounts of energy to provide excessive security for human beings and the city while giving natural processes minimum space. (Yu,2008). This brute maximum approach has increased the cumulative risk of disastrous floods and the vegetated banks which mediated the high flow current have disappeared and caused loss of habitat.

Canalization may appear to provide better flood protection at certain locations and time but leads to greater problems at other points along a river's course. The absence of current attenuation exerts more pressure on the bank walls. The ever-increasing use of impermeable hard surfaces heightens the problem. During heavy rainfall when water runs off directly via storm drains into rivers there are high chances of sudden flood occurrences. Urban river systems with little buffering capacity create extreme and sudden peak discharge (Prominski,2017).

While making provisions about securing surrounding landscapes from flooding a design should not completely overlook the existing ecological functions that exist in any given place. The European Union has formulated an important measure to guide the future design of rivers and waterways through a document called Water Framework Directive (WFD). The WFD provides with assessment criteria for the ecological quality of a watercourse. WFD emphasizes on structural characteristics such as the form of the river channel, biological character, shape of the banks and the structure of the riparian corridor when designing a river corridor, rather putting a singular focus on the quality of water.

Bank erosion is aggravated when the vegetation is removed (Rini et al, 2017). Current-deflecting objects and plant growth attenuate the force exerted by rivers on the banks. When resistance to the flow is higher and flow rate drops. Increased resistance might increase the water levels locally during high water events but, their increased retention capacity relieves the pressure on downstream areas. Where higher water levels cause problems a combination of different measures to enlarge the discharge cross-section, such as setting back the flood limit or excavating the floodplain can be done.

Bank stabilization techniques

A river's floodplain contribute to flood mitigation. Extending the floodplain can be an economical alternative to monolithic barriers. As the water level rises in the river, extending the floodplain allows the water to spread out over a larger area and reduces the flow rate and high water surge, which helps to relieve the burden on downstream areas. There are several ways of mitigating the flood by using various bank treatment techniques. Three of the low cost and ecological alternatives are described here.

i.Seeding of the streambank
ii.Live stakes
iii.Coconut fiber rolls

Figure 8: Streambed which has been graded and seeded (IDNR, 2006)

i. Seeding of the streambank
A mixture of various native grass species and shrubs can be seeded together to reinforce a bare streambank surface. It is the simplest way to stabilize the soil by reducing erosion. The roots create a fibrous network which holds together the soil particle and prevents excessive erosion in the floodplain. The cost of seeding is much lower than other structural erosion control techniques. Even when structural control mechanisms are adopted seeding can always be a complementary erosion control technique.

Ground regrading needs to be done if the slope of the banks has higher than 6:1 horizontal to vertical slope ratio (IDNR, 2006). Enough time should be given for the plants to establish before the high flow seasons.

ii. Live stakes

Tree cuttings can be planted on a graded bank which can grow into mature plants. Attention should be paid that the tree species that are suited for waterlogged conditions. Trees stabilize the streambank by the formation of roots below the ground. The willow trees are some of the best species available for waterlogged conditions, however, there are many other native trees that are well adapted to wet conditions. It is useful to plant these stakes along with a selection of grasses and shrubs. These stakes provide almost immediate erosion control. This is particularly helpful when stakes are available to be sourced locally. Staking can also be used in conjunction with more complex structural reinforcement techniques.

If the slopes are greater than 2:1 horizontal to vertical the ground needs to be graded. Stakes should be 2-3 feet in length, neatly cut, 1.5-2 inches in diameter and installed without damaging the bark. The plantation should be done in the dormant season. About 4/5 of the stake needs to be buried in the ground.

Figure 9: preparation of the live stakes, (IDNR, 2006)

Figure 10: sprouting of a live stake, (IDNR, 2006)

iii. Coconut fiber rolls

The coconut husk fibers are bound together to form a net structure which upon being applied to the streambank surfaces temporarily controls the erosion. The advantage of using coconut fiber is, it is biodegradable and as such makes way for the vegetation to take over after a certain period. The fabric is flexible and conforms to the stream bank. The net-like fabric is fixed in the ground using stakes. The rolls provide erosion control for 6-10 years.

Figure 11: application of the coconut fiber rolls in a wet ground, (IDNR, 2006)

Habitat Conservation

The Terai belt in Nepal is significant in terms of its biodiversity. The ecosystem of tbe Terai is of international significance because it harbors globally threatened species of flora and fauna (Bhuju, 2007). The tropical conditions and wetlands of the Terai are favorable for the habitat of a large range of plants and animals. These wetlands usually host several invertebrates which are food for amphibians like frogs, which in turn become food for snakes and birds. The wetlands have tremendous productive value in a sense that they not only purify surface waters at low cost but also have ecological benefits .

> *"Out of the 833 bird species found in Nepal, the Biodiversity Profiles Project lists 648 species in the Terai and Siwalik Hills. Some 111 of them are species confined to this area alone. The lowland fauna is seen to be more endangered than mid hills or mountain fauna because of greater human activity in the lowlands of the Terai and Siwalik Hills (HMGN/MFSC 2002). Studies indicate evidence of an estimated 1,499 species of flowering plants found at altitudes of 1000m and below." (Bhuju, 2007)*

Flora in the Siddharthanagar

In this rich alluvial floodplain the terrestrial vegetation is mostly dominated by Sisoo (Dalbergia sissoo), Khair (Acacia catechu), Mango (Mangifera indica), Tamarind (Pithecellobium dulce), Simal (Bombax ceiba), Bel (Aegle marmelos), Arecanut (Areca catechu), Kadamba (Anthocephalus cadamba),Mehendi (Lawsonia inermis),Neem (Azadirachta indica), Peepal (Ficus religiosa), Ashok tree (Saraca Indica), Siris (Albizia lebbeck). Bel and Kadamba trees are well adapted to swampy areas.

Flowering plants include Anacylus pyrethrum, Matricaria recutita, Jasminum officinale, Jasminum grandiflorum, Morning glory (Ipomea carnea ssp. fistulosa).

The dominant grass species include the Imperata cylindrica, Saccharum bengalensis, Phragmites karka, and Vetivera zizanoides

The wetlands are the most diverse in terms of the plant composition. They consist of plants that exist in three different strata
i.Submerged species:
water nymph (Naja minor), hydrilla (Hydrilla

verticillata), and hornwort (Ceratophyllum demersum),Vallisneria, Hydrilla, Potemogeton,
ii.Floating species:
lotus (Nelumbo nucifera), wild rice (Hygrorhiza aristata), pondweed (Potamogeton nodosus), Nymphea, Trapa, Eichornia, Water velvet (Azolla imbricata) and Duckweed (Lemna spp.)
iii.Emergent species:
Scirpus, Eleochris, Zizania, Typha angustifolia, Acorus calamus Linn, Polygonum, Leersia, Ipomea, and Oryza rufipogon ; Eichhornia is a problem species in the wetlands (Bhuju,2007).

Fauna in the Siddharthanagar

The tropical climate and abundant water have made the region an attractive venue for migrating birds. The area provides wintering and stopover habitats for waders, waterbirds, and small passerines. Some of the noteworthy species are Grebes (Podiceps cristatus, Tachybaptus ruficollis), cormorants (Phalacrocorax carbo, Phalacrocorax niger), herons (Ardea species), and rare egrets (Ixobrychus cinensis), storks (Ciconia species), ducks (Aythya species), and geese, terns and gulls, birds of prey; rails,coot and waterhens, Jacanas, as well as cranes and kingfishers; storks (Anastomus oscitans and Ciconia episcopus). There are records of 45 species of birds in this area. Bird species symbolic of this area are the Sarus crane, Large grey-babbler, Rufoustailed lark, Slender-billed vulture, and Redheaded vulture and, Greater-spotted eagle (Bhuju,2007). A total of eight globally threatened birds have been recorded which includes White-rumped, Indian Spotted Eagle Aquila hastata, Slender-billed Vulture, Cinereous Vulture and Lesser Adjutant that regularly visit the area (Suwal 2002).

Twenty-five fish species belonging to 12 families and seven orders including the lowland Terai endemics such as Notopterus notopterus and Oxygaster bacaila, threatened species such as the Puntius chola as well as other common species have been recorded here. The fish in this region has an abundant presence in agricultural fields besides being present in the rivers.

The Terai belt has a presence of some of the most poisonous snakes in this region. Snake populations include Bungarus bungaroides, Bungarus caeruleus, Bungarus fasciatus,Bungarus lividus, Bungarus niger, Bungarus walli,Naja naja,Naja kaouthia,Ophiophagus Hannah,Sinomicrurus macclellandi univirgatus (Sharma,2013).

Birds in Focus

Birds are considered as bio-indicators of the ecological wellbeing of a place. Birds in focus in this study are meant to reflect on the scenario of habitat decline of some of the globally threatened species in the Terai belt. Furthermore, this region also presents briefs of feeding and sheltering habits of two representative bird species.

Non-Migratory Bird:
Sarus

The Sarus Crane (Grus antigone) is a globally threatened bird. Sarus is a non-migrant sub-species of the Indian sub-continent (Inskipp and Inskipp 1991). "It is the only resident breeding crane in India, Nepal and Southeast Asia, and is the world's tallest flying bird. Rupandehi district has the highest number of Sarus in Nepal." (Aryal,2009).

Sarus mostly uses rice and Imperata plants as a nesting material when nesting around rice fields. The choice of nesting material is usually dependent upon the vegetation around the nest. Eleochris spp. is used as a nesting material in the wetlands and ponds. Wild rice plants and other vegetation are used in the grasslands for nesting. The Nests are typically partially submerged in water (Inskipp and Inskipp 1991).

The decline of this species is primarily due to the habitat loss (Suwal and Shrestha 1992). Farmlands of the Rupandehi and Kapilvastu districts are the main areas where Sarus cranes breed regularly (Aryal 2004). Egg theft and the hunting of cranes for meat has further aggravated this decline in Sarus population. Meine & Archibald (1996) suggested that wetland conservation of Sarus habitat should be integrated into village-based education for preserving the Sarus crane species.

Migratory Bird
Greater-spotted Eagle

The population of the Greater Spotted Eagle is estimated to be less than 10,000 mature individuals. The largest population of these birds occurs in Russia. Passenger or wintering birds occur in small numbers over a vast area, including central and eastern Europe, North Africa, East Africa, the Middle East, the Arabian Peninsula, the Indian Subcontinent, South Asia and South-East Asia.

This species is suspected to have undergone at least a moderately rapid decline over the last three generations as a result of habitat loss and degradation throughout its breeding and wintering ranges (IUCN, 2017).

It occurs in lowland forests near wetlands, nesting in different types of (generally tall) trees, depending on local conditions. It feeds on an unretrieved quarry, small mammals, waterbirds, frogs, and snakes, hunting over swamps, wet meadows.

Educating about ecological functions occurring in a landscape

Rarely does a city find enough time to assess its regional ecological significance before rapid expansion which creates an imbalance in the environment. An Eco Park is capable of making a culture aware of techniques available to attain sustainability in urban areas. Extrusion of the natural and cultural aspects of a site can help revealing the beauty embedded in functionally sustainable landscapes and as such be used as an educational ground.

The father of modern education, Czech educationist and philosopher Johann Comenius (1592–1670), believed objects from nature could serve as the basis of learning (Comenius et al, 1896). Frank Lloyd Wright explored inspirations for his architectural works in nature, “Look here, fellows. This is what nature produces. These shells all are based on the same basic principles, but all of them are different, and they’re all created as a function of the interior use of that shell.” (Guggenheim,2016). Architecture these days have developed an approach called Bio-mimicry, where constructions are based on building techniques that exist in nature. It is important for this era to learn from and understand the various mechanisms occurring in a naturally sustainable landscape or the civilization will be thrown into jeopardy.

Landscape architecture through its active understanding of ecological processes should responsibly create landscapes that can result in cities with sustainable environments. “If we accept that the current level of ecological consciousness is part of the beginning of a long-lasting, fundamental change in attitudes and environmental values, then landscape architecture must bear a large measure of responsibility for making aesthetic sense out of this attitudinal metamorphosis.” (Lyle, 1996). The presence of media like the National Geographic channel and their presentations has contributed to this culture by making the beauty in the wild visible. It does not have to be a zoo or a botanic garden with plants from all across the planet in order to have an educational value. The accentuation of a naturally occurring phenomenon in a public landscape can help people read and understand a place.

Demonstration of the functioning of a green infrastructure in public parks is one way of conveying this message to a community. For example, constructed wetlands in a public park allow people to see and learn about low-cost water filtration technology and also enjoy a pleasant time immersed in nature. This experience is comparable to visiting a museum. An Eco Park can truly function as an open and culturally appropriate museum that is capable of displaying life-sized portraits of sustainability, which could benefit general public in making them aware of the environment. The presence of native birds, fish, plants, and amphibians creates a dynamic living landscape that has the potential of revealing more about a landscape than just a mere display of an attractive bird in a traditional zoo.

Site selection is one of the critical aspects that determines the educational importance of an Eco Park. The positioning of an Eco Park next to a culturally significant place adds to the educational value. For example, the presence of an Eco park in the vicinity of a primary school can allow schools to organize eco-tours more frequently and let children be acquainted with native plants and animals. Similarly, environmental research institutes can possibly benefit by using an Eco Park as a research facility and document the successes and failures while developing green infrastructures. Keeping Eco parks within the reach and knowledge of the public helps them perform effectively an educational facilities. A greater amount of public engagement in an Eco Park leads to higher educational performance.

An Eco Park stages a multitude of activities naturally occurring in a landscape. By making ecological processes visible to a wider audience it is possible to make the public aware of the concepts of sustainable existence. Locating Eco Parks in culturally significant places helps to engage a larger audience and hence helps achieve a better educational performance.

Synthesis

Constructed wetlands provide a decentralized, sustainable, low-cost solution to treat the various contaminants that can be present in a polluted water. Constructed wetlands are broadly categorized as surface flow and subsurface flow systems. The surface flow system has water flowing in a relatively shallower depth through the system, which brings wastewater in contact with a reactive biological surface. The subsurface flow systems make the water move beneath the surface and have lesser plant contact. The surface flow system relies heavily on the plant material to remove the contaminant, whereas the subsurface flow requires more complex construction with granular strata. A surface flow system is easier to monitor and maintain.

Constructed wetlands perform best when there is a diversity of plant species rather than mono-culture. From the literature, the study builds a synthesized model that incorporates all four plant categories including floating-leaved, free-floating, emergent and submerged species. The depth is best when kept shallow so that light can penetrate the water, oxygen is available to support the growth of the plant and the water comes in contact with a greater amount of plant surface. An organic substrate needs to be present to support floating-leaved, submerged and, emergent plant species. The constructed wetland basin is lined with clay so that the polluted water does not infiltrate and pollute the subsurface water. The width of the channel is an independent variable. The area is determined based on the nature of inflow of the water.

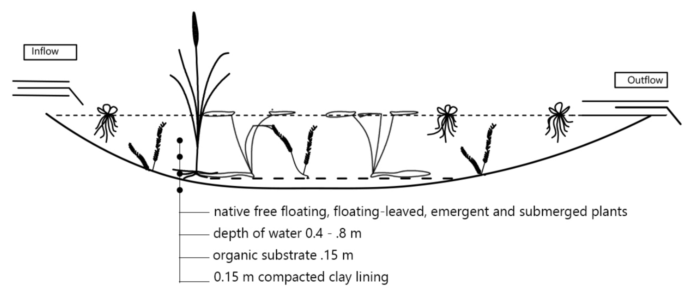

Figure 12: a model that incorporates all 4 categories of planting in a surface flow constructed wetland.

The health of a river system is not solely based on the quality of the water but also on the structural characteristics such as the form of the river channel, biological permeability, shape of the banks and the structure of the riparian corridor. Impermeable monolithic embankments in the river exert pressure on the rivers. Flood areas can be ecologically engineered to help attenuate the forces exerted by the river current. Additionally, the vegetated banks and wetlands along the riverbanks allow diverse plant and animal communities to exist.

The Terai belt shelters many plants and animals that are heavily reliant on wetlands for their survival and therefore conserving the wetlands is of great benefit. Many rare and endangered species take shelter in the wetlands in the region through which the river Danda flows. Constructed treatment wetlands will help in offsetting the historic loss of wetland habitat.

The educational atmosphere is strengthened by the presence of natural areas that allow people to be engaged in nature and develop an understanding of various ecological processes. This helps individuals to appreciate the processes occurring in nature and take an initiative to preserve them.

Design Criteria

The literature has provided different techniques and theoretical underpinnings that can be helpful in designing an Eco Park. The design, based on the literature, aims to cater to five primary areas.

1. Water filtration
2. Bank treatment
3. Habitat development
4. Education
5. Recreation

1.Water filtration:
The Danda river is a slow moving river for most of the year because of the volume of water in the river, a gentle gradient of the river bed and the presence of a check dam. The river, however, exhibits larger flows during monsoon season, which causes flooding in areas surrounding the river.

At present, the pollutants entering the river consist primarily of domestic and agricultural runoffs. These runoffs have contaminants like Nitrite, phosphate, fecal coliform.

An ecologically friendly, low cost, sustainable means of biofiltration should be devised. The pollutants can be removed by using available native wetland species in surface flow constructed wetlands. During plant selection the habitat providing qualities of plants should also be taken into consideration. Similarly, the aesthetic appearance of the plant community should be considered. Alteration of grades in the adjacent feeder channel can enhance the water retention period in these channels and allow more time for the filtration process.

Water testing stations should be located at strategic locations along the channel to monitor the operating efficiency of the treatment facility. The size of the treatment facility should be determined based on the volume and the nature of effluent.

Mobilization of local students, educational institutions, and local youth clubs can play a significant role in monitoring the operation of the facility.

2.Education:
The use of green infrastructure should be made visible; this can be done by using signage accompanied with explanatory plaques.

Interventions made at the various locations should be made visible. Guided tours can help the general populace understand various aspects of the Eco Park. Adjacent institutions, youth volunteers andstudents could serve to explain the value of the ecology of the Eco Park. Local residents could participate in events such as planting and trash pickup to actively engage and learn about the importance of the park.

An Eco park should engage educational institutions for its long-term monitoring and document various aspects of change that it goes through over time, so that it can serve the purpose of environmental research.

3.Bank Stabilization:
It is essential to determine the nature and boundary of the flooded area and adjacent built-up features along a river to determine the best-suited mechanism for bank stabilization.

To provide a sustainable long-term bank stabilization natural means such as planting along the river bank could be used. The habitat sustaining and water purifying features offered along the banks should be paid careful attention to before deciding on bank treatment measures. Plantations that can help the existing functioning of the site and help it stabilize the erosion should be prioritized.

4.Habitat conservation:
A detailed inventory of the native flora and fauna has to be made. The site's habitat generating potential has to be analyze and conserved. The design should make the least possible impact on the natural setting so as not to disturb the already existing habitat at the site.

Careful attention should be paid to feeding, breeding and territorial behavior of the different species which rely on the site.

To minimize human impact on the site a safe distance has to be maintained between the public circulation and critical habitat areas

5.Recreation:
Through an aesthetically pleasing and culturally appropriate presentation of a landscape, a recreational aspect of an Eco Park should be developed. The design of an Eco Park should accommodate activities such as birdwatching, walking and cycling. Provision of walkways and viewpoints should be made. Walkways should be designed to provide various experiential aspects of a site.

Site Selection

The Danda River flows approximately 2 kilometers from the Nepal-India border port of Sunauli. Sunauli is the major port of entry between Nepal and India via land. As an entrance to Nepal, the port has both practical and symbolic significance; it communicates a message about what a place stands for and therefore the increasing level of pollution in the river Danda has become a concern.

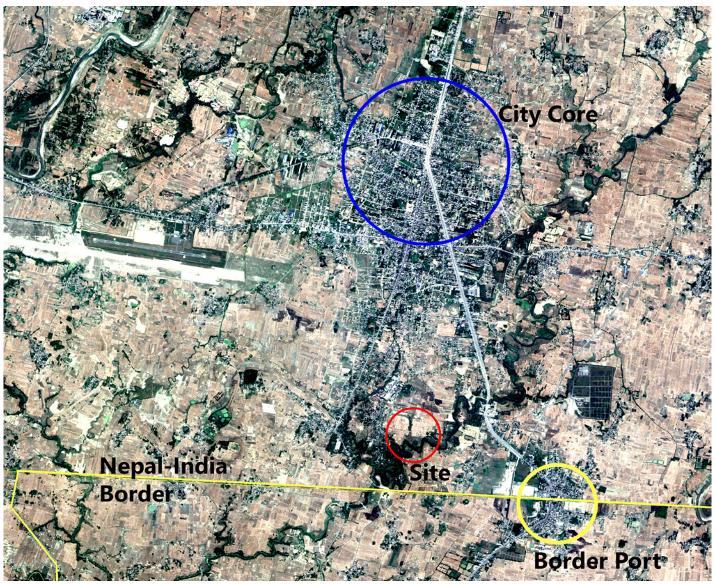

Figure 13: the site's location in rapidly urbanizing city

The site for the Gautami Eco Park lies along the river Danda and is within walking distance from the Sunauli border. The site is surrounded by research-oriented institutes such as Institute of Agriculture and Animal Science (IAAS), Universal College of Medical Sciences, Pratiman-Neema Memorial Health Science Institute (PNMHI) and several schools. The site is located along an educational corridor.

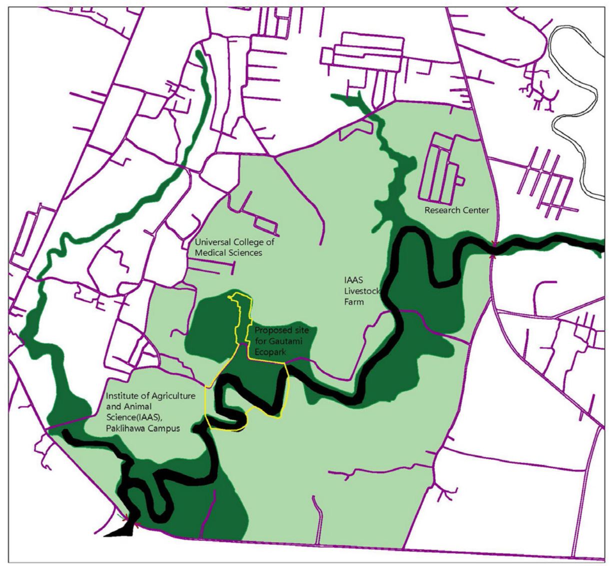

Figure 14: the site's location in an educational corridor

The Nepal Study Center (NSC) is a research center in the University of New Mexico that has been studying the impact of pollution on the Danda River for the last several years. Professor Dr. Alok Bohara from the Department of Economics at UNM is an advisor to the NSC and has been actively searching for a solution to develop a stretch of Danda river.

The site is a 10 minutes walk from the NSC's research center in Nepal and is the largest available wetland that exists in this strech of the Danda river which NSC is trying to develop. This wetland has been impacted by pollution and has an altered sedimentation regime. Five criteria for possible development of the site were laid out which are: wastewater treatment, bank stabilization, habitat conservation, education, and recreation.

The area of the site is 20 acres. The site consists of a feeder channel, river, and wetland. The feeder channel brings the wastewater from nearby paddy farms and other domestic runoffs into the river.

The ultimate source of these ground fed rivers in the Terai is the monsoon rain. The rivers which originate in the Himalayas as a result of snowmelt contribute in maintaining the underground water table which feeds into this river system.

The site lies on the edge of the rapidly urbanizing city of Siddharthanagar. Emptying untreated wastewater and surface runoff from the urban and surrounding area directly into the river introduces several forms of pollutants. The primary pollutants found in the river water are solid waste, Nitrate, Phosphate and fecal E. coli. One of the most important strategies for enhancing the condition of the Danda is treating the wastewater before it enters the river. Environmental awareness and design measures could restore the river and surrounding environment where the site is located.

Site Analysis

The location of the site in Southwest Nepal is in a tropical climate zone. The annual temperature ranges between 72-105 ºF. The average annual rainfall is approximately 55 inches. The area receives approximately 40 inches of monsoon rain every year during June and September. During monsoon months the low lying areas are usually submerged in water and rivers get swollen and become ferocious. The site chosen for the Eco Park remains largely submerged during the monsoon months. Not much activity exists around the river during the monsoon.

During the drier months, November to March, the river is calm and can be used for recreational activities. During these months the current in the river is minimal and the dam built on the Indian side of Danda river creates an almost stagnant condition.

Various educational institutes are situated along this part of the Danda river making possible use of this stretch as a living laboratory. The particular site chosen because the Gautami Eco Park area is the largest stretch of land that gets flooded and is located almost in the midpoint of these institutes.

The site is a fifteen minute walk from the nearest local Jhandi Bazar bus station.

The site gently slopes north to south with a gradient of less than 5%. As the site transitions from the road in the northern part to the river to the south, it supports aquatic, wetland and some riparian habitat. The site supports several globally threatened wildlife species like Sarus Crane, Greater spotted eagle and, Smooth coated beaver.

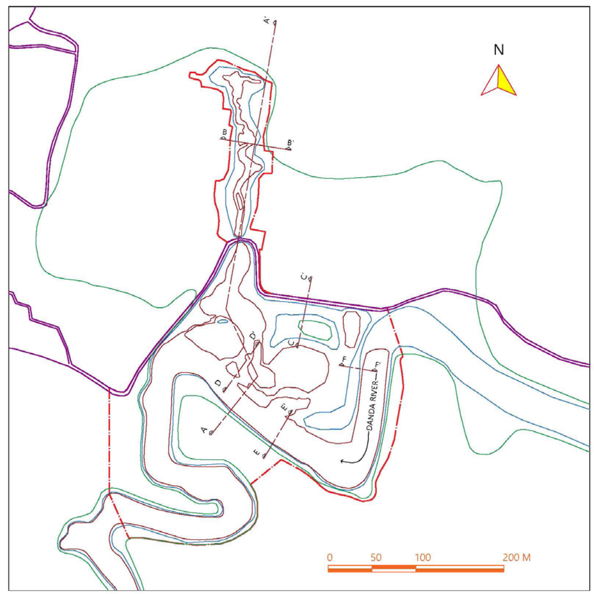

Figure 15: present condition of the site shown in a plan drawing

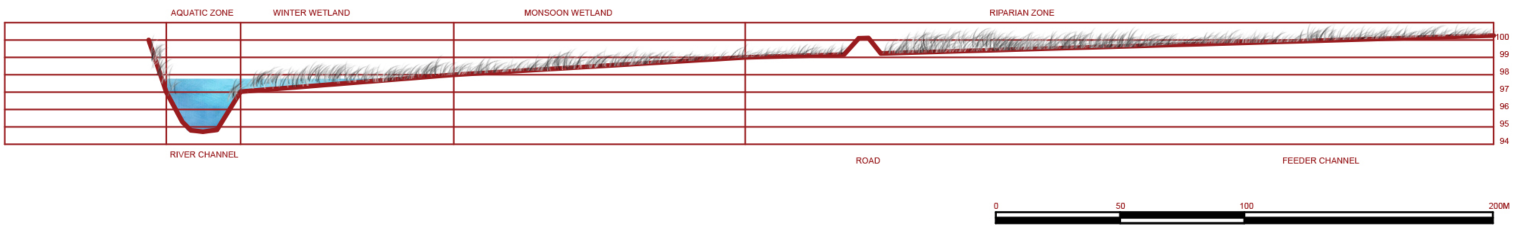

Figure 16: section along A-A’, 7X vertical exaggeration

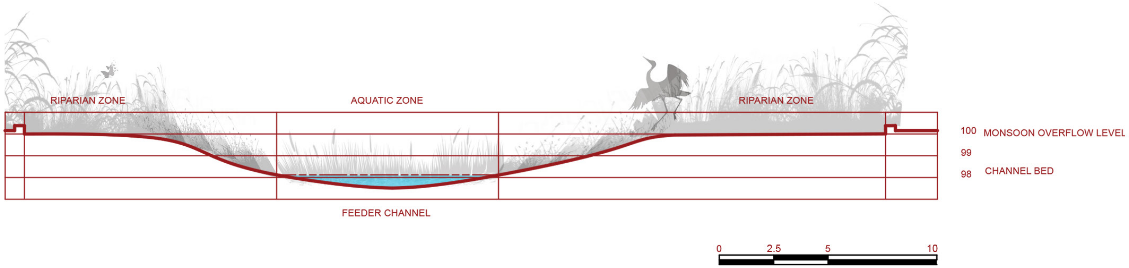

Figure 17: section along B-B′

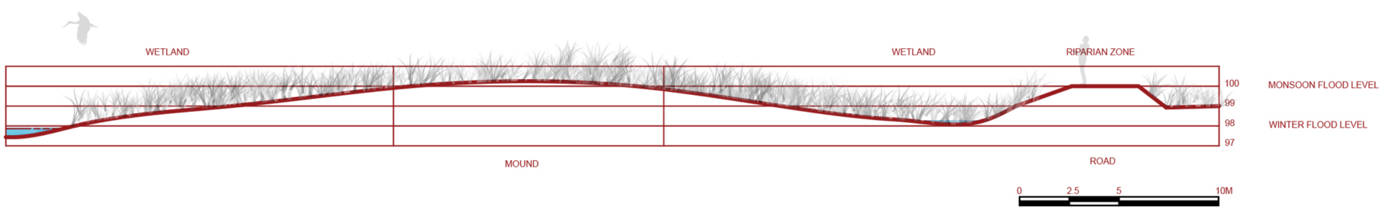

Figure 18: section along B-B′

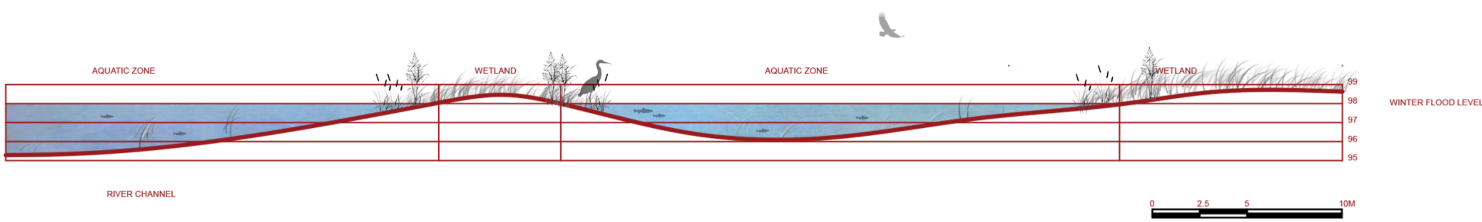

Figure 19: section along B-B′

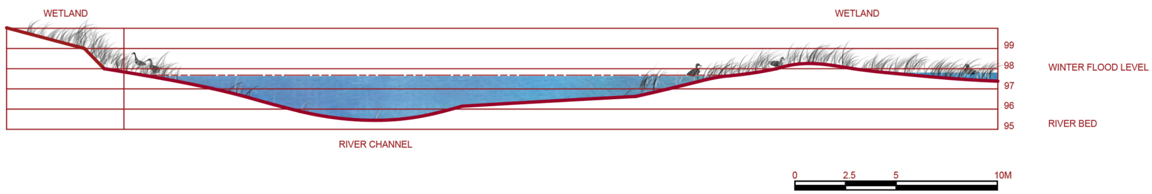

Figure 20: section along B-B′

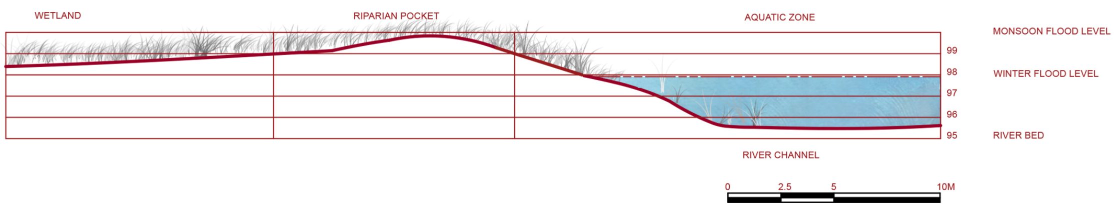

Figure 21: section along B-B′

Design Concept

Industrial grade mammoth water cleansing facilities might appear far more superior but then, even a fragile wild flower growing in the ditches is just as much capable of water filtration, the human species should stop taking pride in creating lifeless zombies and learn from various lifeforms for designing both form and function. This design proposal offers an ecologically viable water cleansing mechanism which can also serve as a tool of place making.

The Gautami Eco Park is located in the vicinity of one of the world's culturally significant historic locations, the birthplace of Siddhartha Gautam Buddha. Buddha was born in a middle of a forest in the Lumbini garden when his mother was in her way to her maternal home. Not much about the landscape features of this ancient garden has been studied. The depictions which are present to us in form of statues suggest presence of ponds with lotus flowers. Historic statues and paintings depict Mayadevi holding on a tree branch as she gives birth to Buddha, Buddha is depicted taking his first steps on lotus flower before he reaches to a brick lined pond.

Lotus flowers have been largely referred to in Buddhist literatures. Lotuses in the Gautami Eco Park will not only filter the water but also as cultural symbol in this landscape. Lotus is a symbol of transcendence, it transcends form the dirty waters of a ditch and blooms delightfully. Floating leaved plants as lotus also allow the growth of submerged plants and also allow ultraviolet radiation to disintegrate pathogens, which helps the water treatment process.

The design challenges the perception that nature can only exist in untouched virgin islands. A sustainable nature of landscape can be a product of architecture which is sustainable and capable of accommodating multiple different species to coexist with human. A sustainable landscape is not an unachievable dream. This project aims to create a landscape which is a 'beauty with brains', a model of sophistication which is worthy of being worshipped.

By creating an edge condition around an existing wetland the project attempts to conserve a precious habitat. The constructed wetland on the northern tip, in the feeder channel, aims to treat the agricultural wastewater to a degree that it does not endanger the habitable conditions in the wetlands that exist south of the channel.

Various points along the walking trail will provide opportunities to experience the Eco Park. Circumambulation is one of the ancient ritualistic form of veneration present in many world cultures. It is believed that through circumambulation one can acquire a well-rounded understanding. Gautami Eco Park has a circumambulatory procession designed around the centrally located conservation area, the circumambulation will allow being acquired with various lifeforms in the conserved area.

This design aims to educate people, to stop and take a moment to appreciate how gracefully the dirty waters in a ditch is being cleaned, to look at and be enchanted with just as much amazement as when seeing *Starry Night*.

Since some of the low lying wetland areas are prone to flood, bank stabilization techniques should be implemented to check the excess flooding in these protected areas.

The service areas are places to locate information centers, maintenance facilities, and similar other essential functions. They are best located at the entrance of the protected zone.The library and information center will monitor pollutants, flora, fauna, erosion and will make this data available to the public.

Design Development

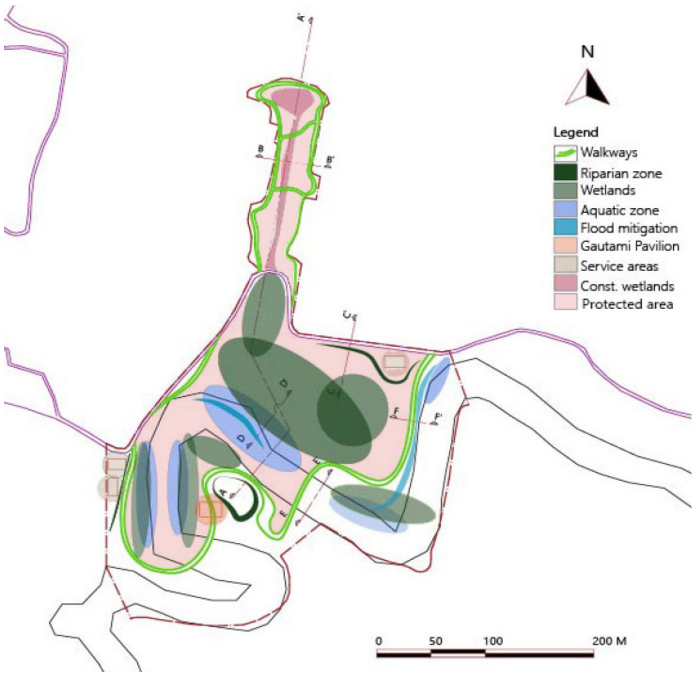

Figure 22: schematic site plan

The schematic plan starts with establishing a boundary around the central wetlands in a form of a walkway. A peripheral walkway limits the human intervention in the site. This preliminary plan further determines where the constructed wetlands, service areas and various design elements can be located.

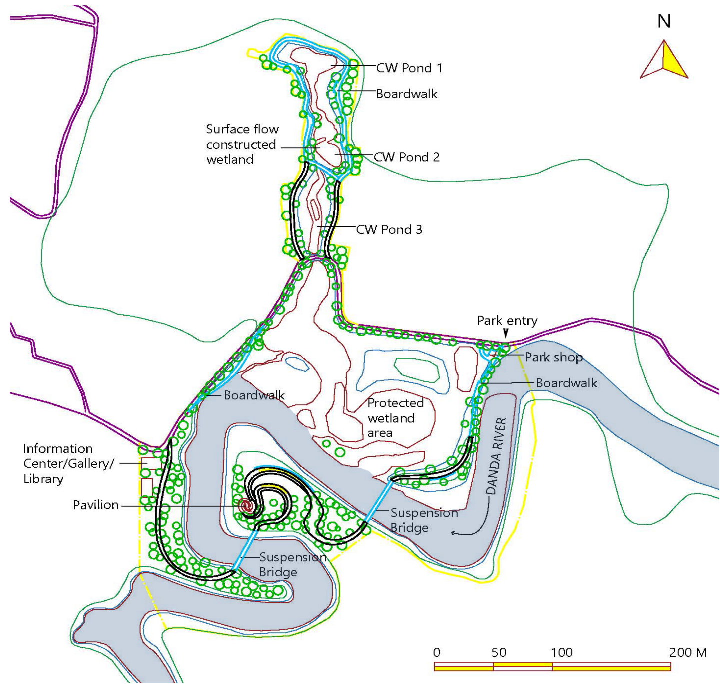

Figure 23: Site plan

This site plan locates various design interventions which would occur in the site.

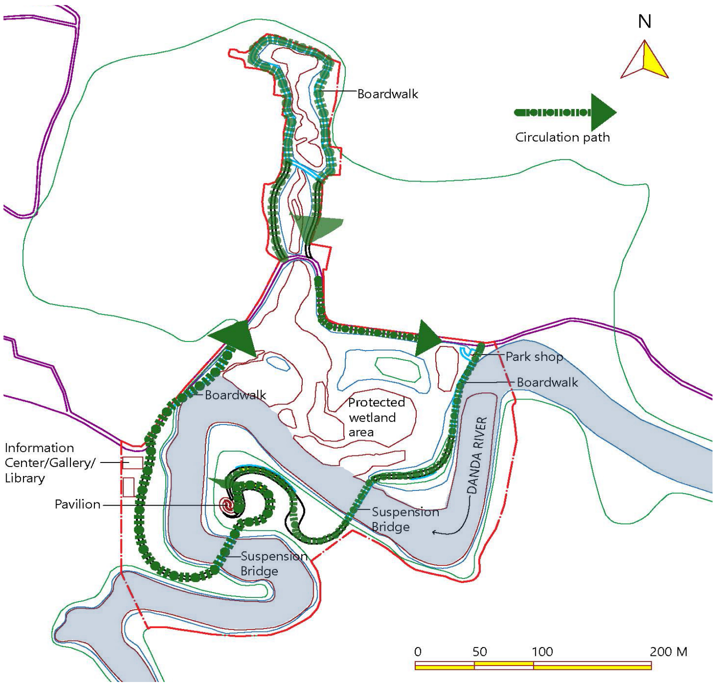

Figure 24: Site circulation

The circulation of the visitors in the park will occur around the perimeter of the site. This type of ambultory path around the site will allow the visitors to understand the physical setting of the park and also understand the functionality. The pavilion is located centrally in the site offers elevated platform to view the protected wetlands.

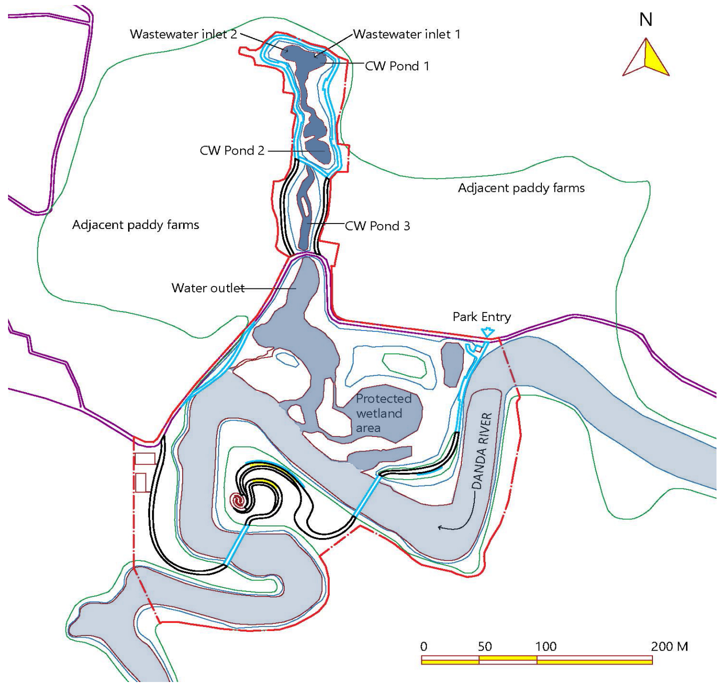

Figure 25: Water treatment phases in the site

The wastewater from adjacent farms is collected in the CW through the inlets located in the northern tip. The water after being treated in the CW enters the existing wetland, it insures the habitable features in the protected wetlands is not affected by the pollutants. The protected wetlands further clean the water before it enters the river.

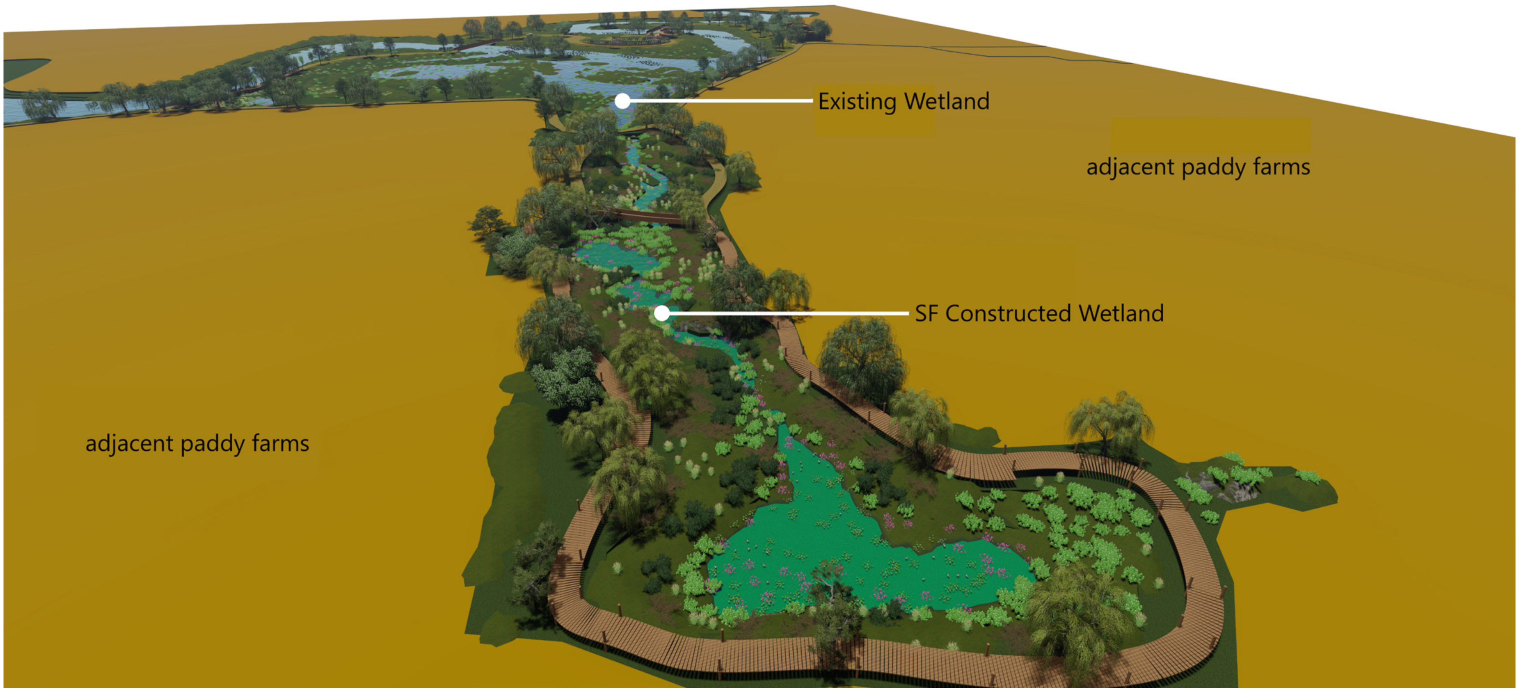

Figure 26: constructed wetland in the channel opening into the existing wetland of the river

Figure 27: longitudinal section of constructed wetland

A series of ponds allow the wastewater to be filtered and subsequently enter the protected wetlands. This CW makes use of locally available wetland plants to filter the wastewater. These CW ponds decrease the amount of nitrate, sulphate, E coli. and similar contaminants which threaten the survival of animals dependent on wetlands for their habitat.

Flowering plants such as lotus not just allow UV to penetrate in the water and kill the pathogens but also add to the scenic value of the CW. Varios locally found plant material used appropriately can add to the aesthethic allure of this functional landscape

Figure 28: Native plants supporting water filtration and habitat funtion in the site

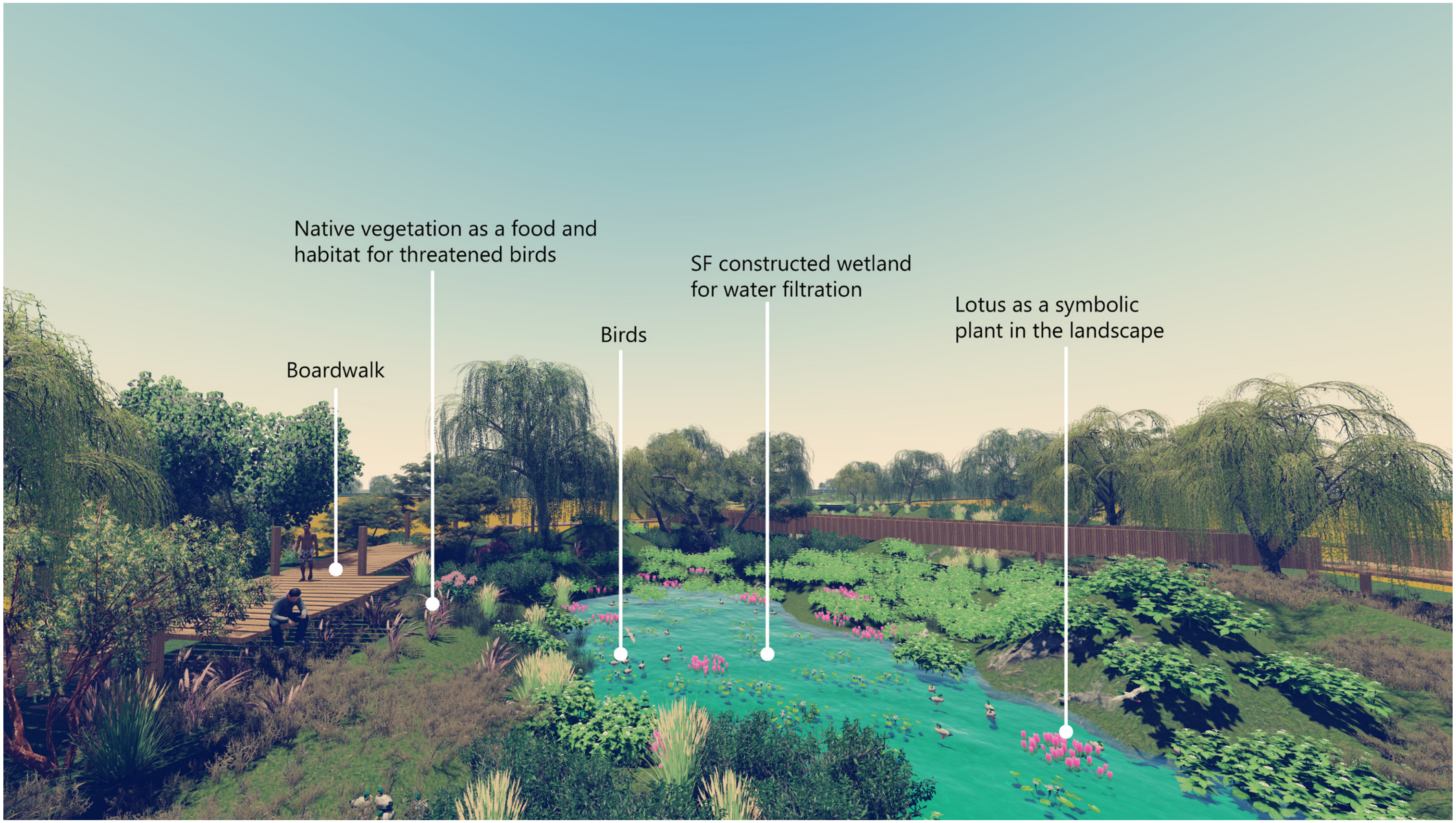

Figure 29: placemaking around a constructed wetland

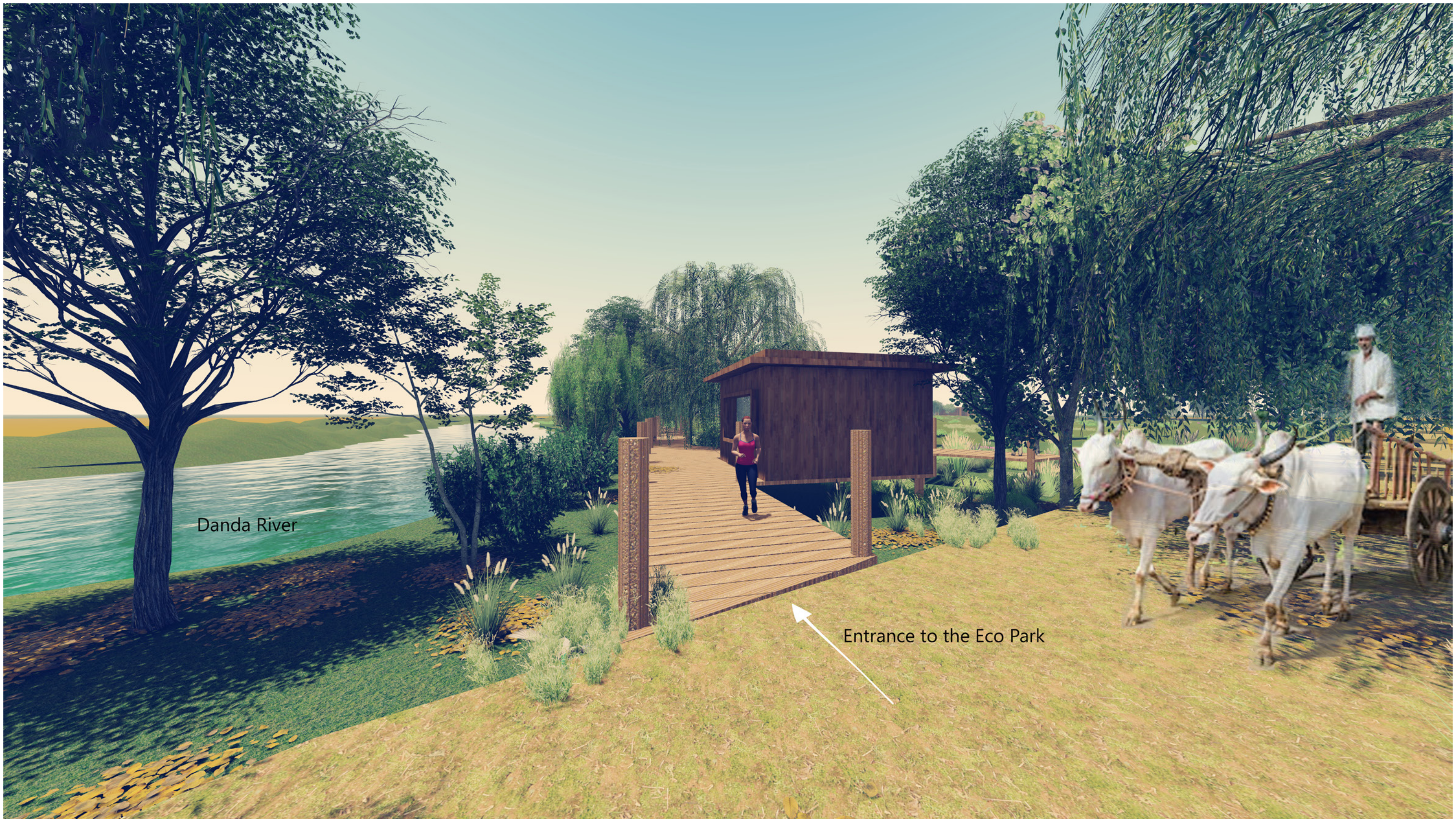

Figure 30: Entrance to the Eco-Park

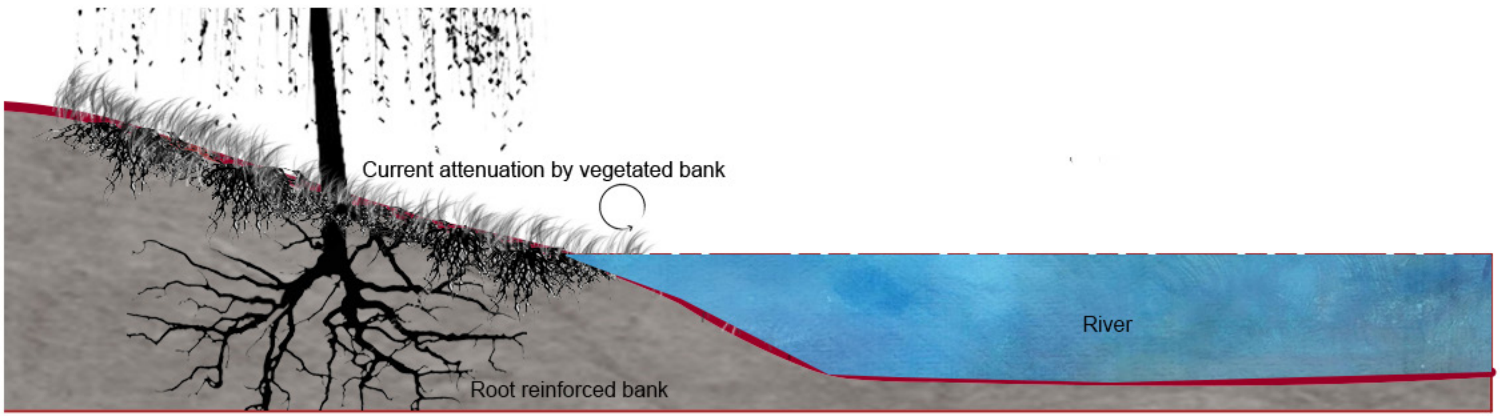

Figure 31: Bank stabilisation achieved through plantation

The plantion of trees , shrubs and grass along the river bank will prevent the excessive erosion. The plant shoots attenuate the water current and the shoots hold on to the soil as a fibrous reinforcement.

Special care has to be given when selecting the tree species to be planted in the riverbanks, especially because not many trees are suited to these water logged conditions. Native trees such as Bel, Kadamba, local willow species are few of the options to choose from.

Apart from preventing the erosion these edges are suitable for amphibians to freely move from banks to river.

This kind of bank condition allows flood to reinstate the nutrients in soil without letting significant damage the landscape.

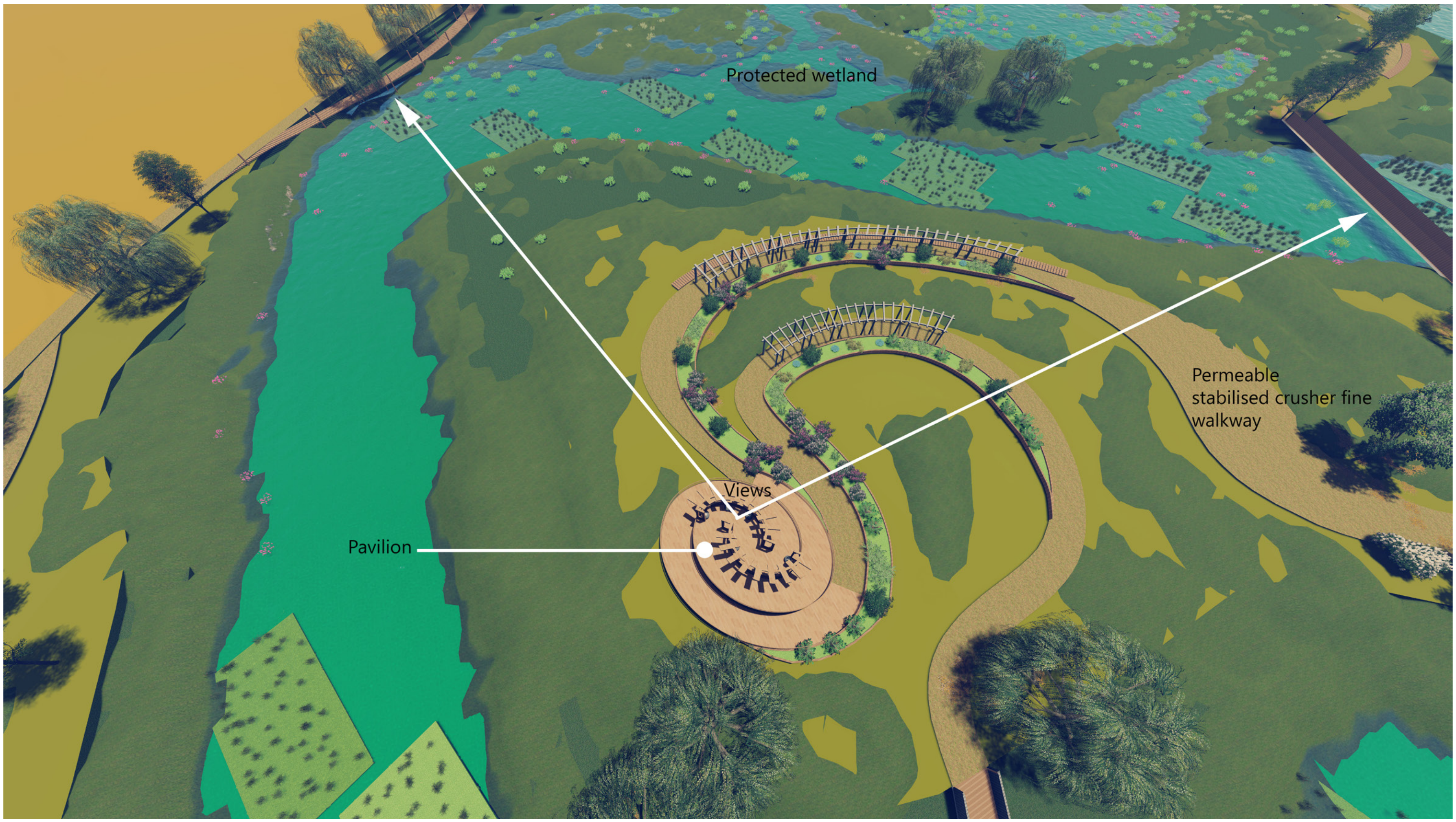

Figure 3: the pavilion at the center of the site which offers view into the protected wetland

Discussion and Analysis of Findings

The design provides a solution to treat the wastewater which would otherwise enter the river untreated. This filtration process has been designed to be accommodated in an existing channel. The surface flow constructed wetland system incorporates natively present plant material to aid this filtration process. The use of native plants allows this constructed wetland to be low maintenance and hence an economical solution.

Through the plantation of the river banks the design provides a solution to sustainably cope with the flood and erosion issues.

By defining an edge to an existing wetland the design preserves the habitat supporting features of this site. Further, through plantation of native plants which are significant to survival of threatened and vulnerable species the habitat value of the site has been reinvigorated. The reduction in pollutants entering the river system helps create habitable conditions beyond the site boundaries.

The design reflects on the history and culture of the place by making use of symbolic elements such as lotus flower and the spiral pavilion.

The design makes it possible to read the ecological and cultural setting of the site and as such understand the place. The design educates people about the natural and cultural environment through providing them an opportunity to experience the Eco Park. Apart from providing visitors an opportunity to be environmentally aware the Eco Park also serves as a living lab to the surrounding educational institutions.

The design has made an exploration of the different ways through which creation of a more sustainable landscape is possible. Gautami Eco Park presents a remedy to water pollution issues in the rapidly urbanizing city Siddharthanagar. Apart from providing immediate solution to the environmental problems it also is a tool to build environmental awareness. It will be the first Eco Park in Nepal, its low maintenance, relatively inexpensive construction, culturally sensitive feature makes it well suited to be adopted.

Conclusion

Eco Parks have a tremendous potential to allow cities to tackle many environmental problems and help them become more sustainable. Eco Parks do justice to both natural and cultural ecological settings of the cities. The Eco Parks are very flexible in terms of design and can suit to almost anyplace. The sustainable and economical feature of an eco park make it very suitable for use.

There needs extensive research to determine critical habitat locations around the world in order to safeguard threatened and vulnerable animal and plant species. Rapidly growing cities and townships can have detrimental effects in the ecological hotspots.

Landscape architecture as a practice should dedicate itself to keep the ecological integrity of the place intact, this should start with extensive study about the functioning of ecological and cultural systems.

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