IOSR Journal of Multidisciplinary Research (IOSR -JMR)
ISSN: 3048-7439 Volume 2, Issue 6, Series 2, Nov. - Dec. (2025), PP 31-40
www.iosrjournals.org

Constructed Wetland Wastewater Treatment System In Landscape Architecture

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Abstract:
Nowadays, global warming caused by the environmental crisis was a major international issue that was desperately being solved. It dramatically caused the climate change in several areas. For this reason, environmental conservation was sustainably necessary for community development, especially the pollution management of the communities. The constructed wetland wastewater treatment system in landscape architecture was a guideline for wastewater treatment before being discharged into the environment using natural methods. It enhanced the aesthetic value of living with nature by green landscape architectural design. The constructed wetland wastewater treatment system model was applicable to various landscape architectures with the environmental conditions. Therefore, the research objectives were a model design of a green cultural landscape in the sustainable environmental conservation, the landscape architectural design for flood resilience and the sustainable cultural promotion in the local communities. To the research methods, they were the study of design criteria for the constructed wetland wastewater treatment system, applying to the study's area by landscape architectural design and the research conclusion about a model design of the constructed wetland wastewater treatment system with flood resilience from a university-based case study in University of Phayao. Since the university's location was among the mountain and full of green landscapes. The university areas were perfect to designs of the constructed wetland wastewater treatment system on the slopes and the plains. Furthermore, the university's image was a community educational institution with the practical academic services to the local communities and promoted the environmental conservation to the new generations.
Key Word: *Landscape architecture; Wetland; Wastewater treatment system; Site planning.*

Date of Submission: 09-12-2025 Date of Acceptance: 19-12-2025

I. Introduction

Figure no 1: The location of The University of Phayao.

Due to the environmental crisis, many countries had realized the extreme natural disasters and issued environmental conservation policies, such as those in Thailand. The various Thai organizations, including the University of Phayao, extensively promoted green vision actions. It was ranked in The University of Indonesia (UI) Green Metric World University Rankings to measure its sustainability efforts launched in 2010. Until now, the UI green metric had become known as the first and only global sustainability university ranking. In 2024, The University of Phayao ranked 9th in Thailand out of 59 universities and 106th in the world from 1,476 universities worldwide, better ranked from 2021 (171st in the world). The assessment criteria were based on the setting and infrastructure, the energy and climate change, the waste management, the water management, the transportation, the education, and research. Therefore, the constructed wetland wastewater treatment systems in landscape architecture were researched in the university's sustainability efforts to become a global eco-friendly green educational institution [1].

To the scope of this research area, it was a main ditch area at The University of Phayao hotel buildings. The hotel location was on the hill inside The University of Phayao. The hotel buildings were spread around the hill with slopes and opened to hill views. The main ditch of the hotel area was the lowest area of this hill and had a natural pattern. The wastewater was drained from the buildings on the hilltop to the foothill before being drained into the university's wastewater treatment system. Hence, this foothill area was a good case study in landscape development for environmental conservation, aesthetics, resiliency, social equity, health, and wellness. The research framework was a landscape architectural design of a constructed wetland wastewater treatment system in the case study's area as a sustainable model and the design guideline of constructed wetland wastewater treatment system in landscape architecture.

Figure no 2: The Valley of The University of Phayao building group.

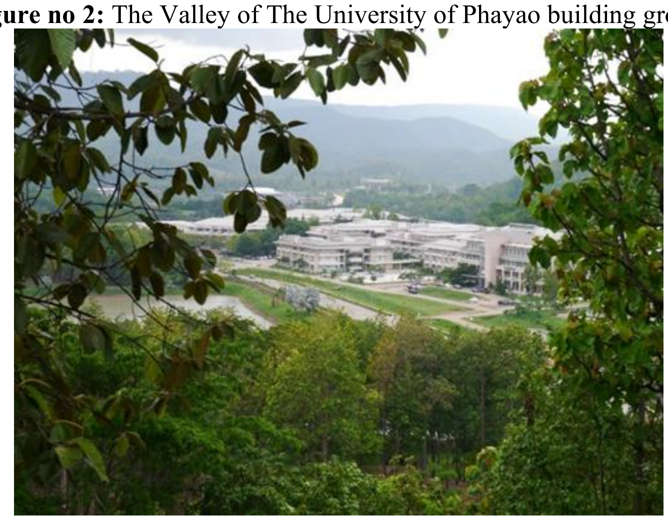
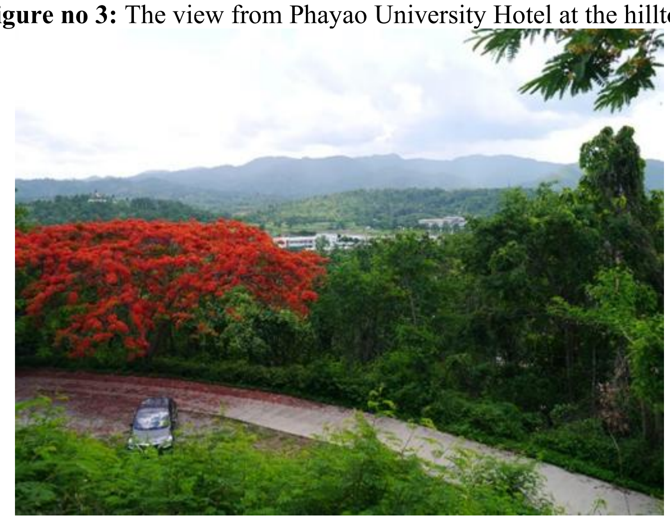
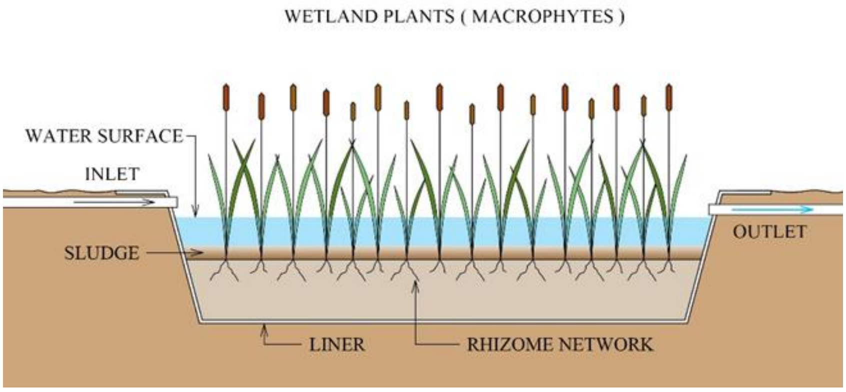


Figure no 3: The view from Phayao University Hotel at the hilltop.



Due to site geography, the constructed wetland wastewater treatment system was appropriate for the surface flow system or free water surface (FWS) because water flowed over a vegetated soil surface from an inlet point to an outlet point. The system design had a natural wetlands pattern, but the study area was not a large plain. This made the system pattern adapted to a stream with a waterfall. The free water surface wetland design included 4 parts: a wastewater inlet, a deep inflow trench or pool with water depth varying between 12 and 30 inches, dense emergent vegetation perpendicular to flow direction, and a distribution pipe with cleanouts. The water depth depended on the system design for more wastewater treatment efficiency.

Figure no 4: Schematic of the Free Water Surface Constructed Wetland [2].



II. Material And Methods

Objectives

Designing a model of the constructed wetland wastewater treatment system for a green cultural landscape in sustainable environmental conservation.
Designing the landscape architectural guideline for flood resilience.
The sustainable cultural promotion in the local communities.

Literature reviews

Wetlands
In The Ramsar Convention, 1971 (Article 1.1 and 2.1) were defined:

Article 1.1, "Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed six meters."

Article 2.1, "May incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands."

In addition, there were human-made wetlands such as fish and shrimp ponds, farm ponds, irrigated agricultural land, salt pans, reservoirs, gravel pits, sewage farms, and canals. The Ramsar Convention was grouped into three categories: marine and coastal wetlands, inland wetlands, and human-made wetlands [3].

Constructed wetland

A shallow basin filled with some substrate, usually soil or gravel, and planted with vegetation tolerant of saturated conditions. Water was introduced at one end and flowed over the surface or through the substrate. It was discharged at the other end through a weir or other structure that controlled the depth of the water in the wetland.

Constructed Wetland Systems were natural wastewater treatment systems. There were 2 types of constructed wetland systems;
(i) Surface Flow System or Free Water Surface (FWS) – Most natural wetlands were FWS systems. Water level was above the ground surface, and vegetation was rooted and emerged above the water surface. Water flow was primarily above ground.
(ii) Subsurface Flow System (SFS) - The water level was below ground, and water flow was through sand or gravel penetrated to the bottom of the bed [4].
Thailand also used both systems for the natural wastewater treatment systems.

Plants in constructed wetlands

The planting design should match the species to the hydrology. The most frequently planted species were the following;
(i) Typha latifolia – Cattail (common in North America)
(ii) Phragmites australis - Common reed (very common in Europe and Asia)
(iii) Typha angustifolia - Narrowleaf cattail
(iv) Juncus effusus - Common or soft rush
(v) Scirpus (Schoenoplectus) lacustris - Bulrush
(vi) Scirpus californicus - California bulrush
(vii) Phalaris arundinacea - Reed canary grass
(viii) Eleocharis – Spikerush [5]

Methods

The study of design criteria for the constructed wetland wastewater treatment system and application to the study's area by landscape architectural design.

The data analysis and synthesis for the research conclusion about a model design of the constructed wetland wastewater treatment system with flood resilience from the case study.

Research public relations.

III. Result

The constructed wetland wastewater treatment system case study involved the foothill and main ditch areas of Phayao University Hotel, located at the University of Phayao. The three parts of the design explanation were the following;

Site analysis

Geography

The University of Phayao was located in the area of a national reserved forest in Phayao province, a province in northern Thailand, on Phahonyothin Road (National Highway 1). The university was located on a hill 500 meters above sea level, among the dry dipterocarp forest. Its coordinates were 19.03º N and 99.90º E. Phayao geology was the alluvial deposit or soils deposited in riverbeds, the same as the University of Phayao. The soils consisted of silt, sand, clay, and gravel, and had varying water permeability. However, the soils around the case study's hill were sandy loams and laterites with low water absorption. Therefore, the landscape architectural design should consider the soil characterization in water absorption.

Climate

Phayao had a tropical climate. In winter, there was much less rainfall than in summer. According to the Köppen and Geiger climate classification system, Phayao's climate was classified as Aw; Tropical savanna climate with dry-winter characteristics. The average temperature was 25.4 °C or 77.7 °F. The annual rainfall was 1,344 mm or 52.9 inches. In this climate, the dry season could become severe, and drought conditions often prevail during the winter season from December until March. There were heavy rainfalls and strong winds on the study hill in the rainy season. These caused landslides and damaged the surroundings around the hill [6].

Biodiversity

Plant

The study area was in the dry dipterocarp forest, which was mostly found in northern Thailand and was a deciduous forest. The example plants in this forest were Gurjan trees, Siamese Sal trees, Burmese Sal trees, Indochinese Keruing trees, and Hairy Keruing trees. The plants in the buildings were garden trees such as golden dewdrops, Chinese ixoras, flame trees, palms, etc. Therefore, the disadvantage of the study area was the risk of wildfire occurrence because of the deciduous forest. During the dry season, the forest trees changed colors and shed leaves. These made the forest floors covered by the dry leaves that were good fuels for occurring wildfires.

Animal

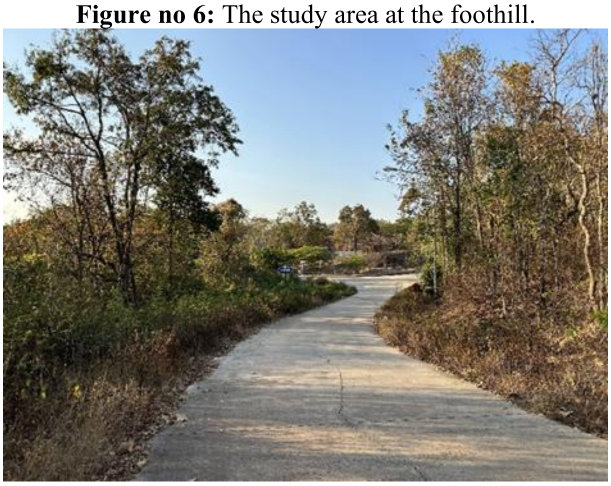
The study area only had small wildlife animals because the university location was in the community area. However, some study areas had overgrown bushes and grasses beside the walkways. Hence, the venomous animals from these areas could endanger the pedestrians passing by.

Cultural attribute

The buildings around the study area were a group of the University of Phayao's hotel and some university buildings. The university hotel was a famous hotel school in the northern region. It was established in 2005 and redeveloped to complete a hotel school in 2008. It was a large hotel containing 154 guest rooms. It offered short-term and long-term services. The hotel buildings were linear along with the site contours and dispersed from each other as a resort. All building structures were reinforced concrete structures. In the hill area, there was no university bus stop. The hotel's accessibility was by private car, cycling, and on foot. The university's land use was blue code for institutional and public facilities. This area's building regulations followed the local and university building laws. Thus, the new land developments in the university should be concerned with these design regulations.

Figure no 5: Phayao University Hotel Building.

Figure no 6: The study area at the foothill.



User

According to the design areas, they were beside the main road of the university, as well as the university gates, and on the hill, as the hotel landmarks. The university students, employees, and visitors were the users at the university gates. Regarding the hotel landmarks, most users were university employees who stayed at the hotel, and university visitors.

Site problem

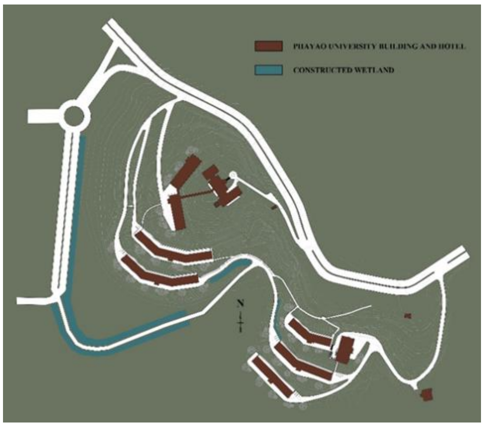
From the site survey, the collected site problems were as follows:

(i) Water absorption of soil – The site soil had water permeability.
(ii) Slope of the hill – The hill roads were steep without the guardrails.
(iii) Lack of universal design – Universal design was a new technology. However, the study area's buildings and surroundings were old and had not been developed for a long time.
(iv) Venomous animal – The site surrounding was the forest. The bushes and the grasses in some parts were overgrown. The venomous animals from the forest could endanger pedestrians.
(v) Landslide – According to the site geography, the study area had a landslide risk in the rainy season.
(vi) Drought conditions in winter – The site forest was dry without water resources, which easily caused wildfire.
(vii) Wildfire – There was no fire barrier to break the wildfire before it spread to the university buildings.
(viii) Storm – There was no storm shelter and no water absorption area at the site.
(ix) Difference in the flowering period – The flowering period of the flowering plants at the site was only in the summer.

Landscape architectural design

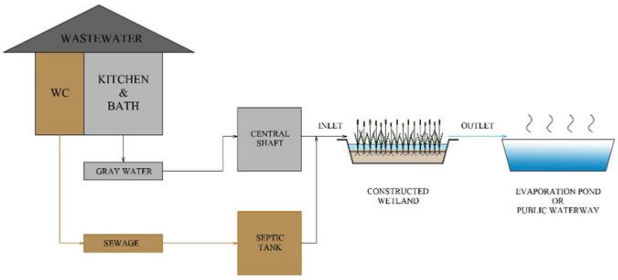
The schematic design of the constructed wetland wastewater treatment system was adapted to the landscape architectural design of the case study. The wastewater treatment system in design was the free water surface system. The constructed wetland shape was linear, with the steps following the hill contours. Hence, the landscape design had the character of a step garden.

Figure no 7: The blue zone of the constructed wetland wastewater treatment system in the study area.



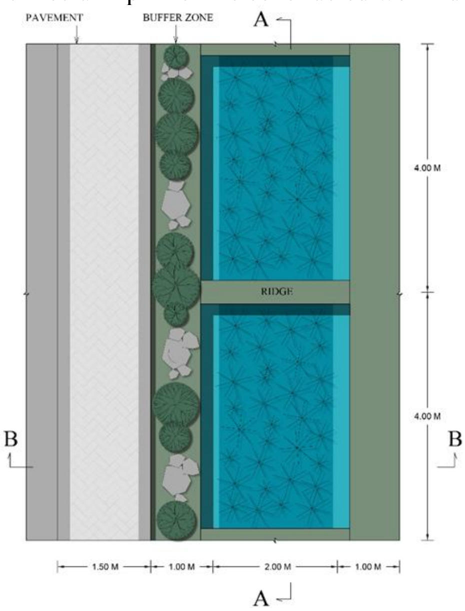
On the site plan, the brown zones were the university buildings and the hotel on the hill. The blue zones were the areas of the constructed wetland wastewater treatment system at the foothill and the main ditch of the university hotel.

Figure no 8: Diagram of the constructed wetland wastewater treatment system.



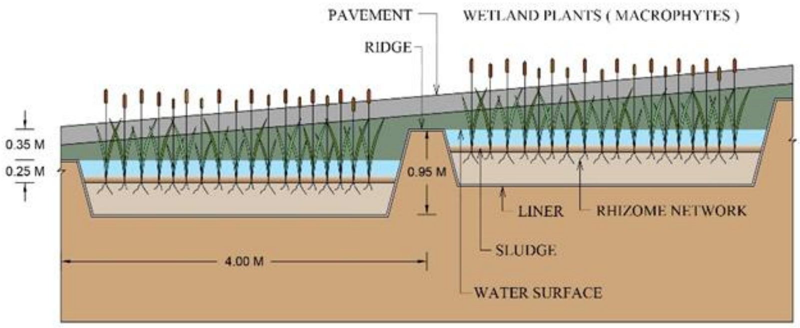
The diagram of the constructed wetland wastewater treatment system showed two lines of wastewater from the building. The gray line was the wastewater from the kitchen and the bath. This line was allowed to be used in the constructed wetland wastewater treatment system directly before discharging the treated wastewater to the evaporation pond or the public waterway. The brown line was the sewage from the water closet. This line was necessary for treatment in the septic tank before discharging to the constructed wetland wastewater treatment system and then to the evaporation pond or the public waterway.

Figure no 9: The landscape architectural plan of the constructed wetland wastewater treatment system.



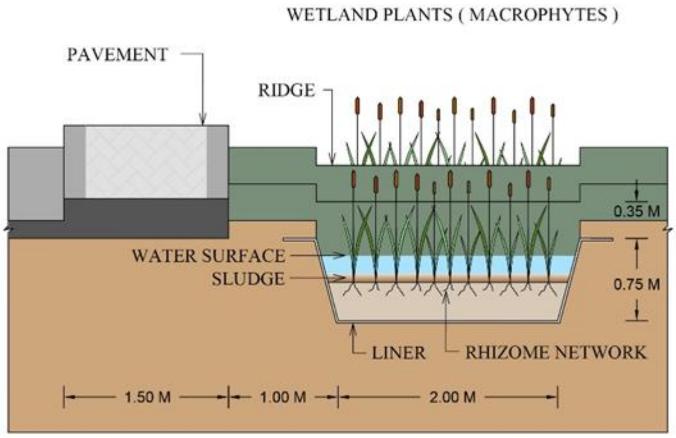
For the landscape architectural plan, the constructed wetland wastewater treatment system was designed beside the university road, which has pavement for pedestrians. The buffer zone was the green barrier for protecting the pollution from the constructed wetland basin, which included bushes or pavement setbacks. The constructed wetland basin size was 2 meters wide and 4 meters long, with the ridge per unit or a gardening step.

Figure no 10: The long section (A-A) of the constructed wetland wastewater treatment system.



In detail of the long section (A-A), the components of the constructed wetland wastewater treatment system were the basin with a liner, the soil for the rhizome network, the sludge from the wastewater, the ridge, and the wetland plants. The basin was 0.95 meters high and left a space for the water surface level at 0.25 meters high. The sludge was 0.15 meters high, and the soil at the basin bottom was a minimum of 0.30 meters high.

Figure no 11: The cross-section (B-B) of the constructed wetland wastewater treatment system.



In detail of the cross section (B-B), the constructed wetland basin was set beside the university road and had a space of about 1 meter between the road and the basin for the buffer zone. The pavement was designed beside the road for pedestrians. The pavement dimension should be a minimum of 1.5 meters wide for public space according to the building regulations [7]. The ramp or the sloped pavement should be 1:12 for persons with disabilities and the elderly in public spaces [8]. These building regulations were the design criteria of the stepped wetland basin.

Material
(i) Pavement – The pavement material should have permeability for rain drainage and flooding protection.
(ii) Basin – The basin structure was made of rammed earth form or a concrete basin with a liner at the bottom.
(iii) Ridge – The ridge was made of the same basin material with a strong structure and water leak protection, such as an adobe structure, rammed earth form, or concrete structure, etc.
(iv) Liner – The examples of eco-friendly liners were Bentomat and puddling clay. Bentomat, geosynthetic clay liners, also known as bentonite mats, had been used as a natural method for sealing against liquids and gases in various applications [9].

3.2.2. Plant

(i) Buffer zone – The buffer zone was a green zone with natural plants or green materials for protecting the pollution from the constructed wetland basin. The examples of the shrub were Golden dewdrop, Cape Leadwort, Rose, Snake plant, Fukien Tea, and Agave, etc. Examples of green materials were bamboo fences, wood fences, stone fences, or brick fences, etc.
(ii) Wetland – The wetland plants were macrophytes or aquatic plants. Examples of aquatic plants were Cattail, Common reed, Lotus, Papyrus, and Vetiver, etc.
3.2.3. Resilient design
(i) Universal design – The universal design was a design for all without physical conditions. There were seven principles for all design criteria, not only for architecture but also for artwork. The seven principles were as follows:
Principle 1: Equitable use
Principle 2: Flexibility in use
Principle 3: Simple and Intuitive use
Principle 4: Perceptible information
Principle 5: Tolerance for error
Principle 6: Low physical effort
Principle 7: Size and Space for approach and use [10]
(ii) Landslide protection – The constructed wetland basin was a natural barrier to break the landslide from the hill to the building area. The basin width was flexible to accommodate a gap between the forest and the building appropriately.
(iii) Wildfire protection – The constructed wetland basin was a firebreak without fuel materials. The basin width was flexible to architectural setbacks, at least 6 meters from the forest, for wildfire protection. The proper architecture setback of at least 6 meters was due to the building regulations and the constructed wetland basin width [7].
(iv) Storm protection – The landscape architectural design used materials with permeability for rain drainage and flooding protection. The constructed wetland basin helped in water absorption and drainage. The big trees were the storm shelters and the site's shades.
(v) Flooding protection – Apart from the water absorption and drainage of the constructed wetland basin, the basin could be designed as a ridge for the flood barrier of the area.
(vi) Good maintenance – The good maintenance in landscape architecture was the self-management design for plants and the wetland basins. It was a natural way to achieve energy efficiency in landscape maintenance.

IV. Discussion

From the landscape architectural design of the case study, there were two summary parts in the design criteria. The first part was the landscape architectural design criteria of the constructed wetland wastewater treatment system. And the second part was the design guideline of landscape architecture for flood resilience.

The landscape architectural design criteria of the constructed wetland wastewater treatment system
Site geography - The shape of the constructed wetland basin depended on the site geography.
Diversity of plants and appropriate plant selection - The appropriate plant selection helped in comfortable maintenance by considering the plants with long lives, strong roots, climate change adaptations, cycles, falling periods, flowering periods, and local identities. The plant diversity helped the landscape aesthetic for all seasons with good maintenance.
Appropriate landscape architectural material selection - The appropriate material qualifications were local and green materials with strong structure, heat reflection, noise absorption, and permeability for energy efficiency, as well as good drainage and a buffer zone.
Good universal design - This was concerned with the universal design in landscape architectural design for all users.
Site landmark design - Making the constructed wetland basin in landscape architecture a site landmark by using basin shape and size, plants, view design, step garden, or landscape decoration in design.
Site identity creativity - Creating the site identity by using local identity in design, such as local plants, animals, or symbols. Moreover, a strong sense of place would make the place recognized easily and differentiate it from others.
Green buffer zone of the site - Designing the buffer zone as a green barrier for protecting the site from pollution. The green zone made the site shaded and walkable, including being a shelter from disasters.
Safety - All landscape architectural designs had to be safe for all users and the environment.
Wastewater management - The wastewater must be treated by the constructed wetland wastewater treatment system before discharging into the public waterway.

Good maintenance – Good maintenance in landscape architecture included energy efficiency, environmental conservation, and time and cost savings.

Figure no 12: Landscape perspective.

The design guideline of landscape architecture for flood resilience
Reservoir or wetland preparations in the communities for storing the waters from natural waters and floods.

Wastewater treatment before outlet to the wetland areas or public waterways by the constructed wetland wastewater treatment system or others.
Designing the wetland areas for the recreation areas of the communities.
Making the wetland areas landmarks of the communities.
Designing the wetland areas to be buffer zones for the communities to protect the disasters.
Landscape architectural design with sustainability for wetland areas.
The participation of people in the communities in local wetland preservation.
Self-management design for wetland areas in comfortable maintenance.

V. Conclusion

From the case study, the aesthetic of the constructed wetland wastewater treatment system was created by landscape architectural design. The design guideline clearly explained the details of the constructed wetland basin for building in other places. The popular wetland wastewater treatment system was a free water surface system, well-suited for landscape design. It could be used in private and public sectors for public spaces. In the community's public space, the constructed wetland basin was the water absorption area for flood resilience and recreation. Moreover, the higher basin above the ground, as the ridge, was able to serve as a flood barrier. To the reservoir of the community, the constructed wetland basin had to be set apart from the public reservoir to protect the pollution of the public water resources.

Figure no 13: University reservoir.

The architectural design values of the constructed wetland wastewater treatment system in the community were the following;
Social design value - The good participation of people in the community in environmental conservation together.
Environmental design value - The good built environment for everyone, and making the livable city.
Traditional design value - Enhancing the sense of belonging for cultural heritages to the new generation in preservation.
Gender-based design value - Enhancing the equality in public space by universal design.
The economic design value - Making the constructed wetland a tourist attraction for promoting local tourism.
The novel design value - The innovation of wastewater treatment systems using natural methods in sustainable development.

Acknowledgment

This research was part of the sustainable development goals in landscape architecture and urban planning, following the visions of the university and the architectural department. It was supported by the School of Architecture and Fine Arts at the University of Phayao. Thanks to everyone who assisted and were not named in this research.

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