PROJECT INNOVATIONS AND KNOWLEDGE DISSEMINATION

I. PROJECT INNOVATIONS

A. Distributed Wastewater Management System

Collection and treatment of wastewater in rural areas are challenges in the People's Republic of China (PRC) as the number of households and other buildings is smaller than in urban areas and they are scattered. In Zhaotong City particularly, rural areas are located in remote mountainous areas with difficult terrains and big elevation differences. These conditions make it very difficult to install wastewater collection pipes to transfer wastewater to one centralized wastewater treatment plant (WWTP). Thus, this project takes an innovative approach to use distributed wastewater management systems.

Flexible layout and low cost of pipe network. Distributed wastewater management systems can be developed close to wastewater sources and their layouts can be flexibly arranged according to the topography and the locations of households and other buildings. This flexibility greatly reduces cost of wastewater collection pipe network and overcomes the problems of terrains with large elevation differences and scattered households and other buildings. Quality of wastewater treated by distributed wastewater management systems meet the Grade 1A effluent standards similar to centralized WWTPs. Distributed wastewater management systems demonstrate good rural wastewater management.

Figure 1: Distributed Wastewater Management Systems

Small size and low operation cost. Size of a distributed wastewater management system is small and needs only a small area. It can be developed in a field or anywhere in a rural area. Due to the small size, there is no need to set up routine supporting facilities such as a duty room and sludge treatment facility. Because of the small size, the operation and maintenance personnel and operation cost can also be reduced. In short, this approach is better suited for management of rural wastewater.

Use of solar renewable energy and operation cost reduction. Solar panels can be installed in small wastewater treatment facilities. Solar panels provide some operating electricity and reduce operating costs of the facilities. The energy-saving and emission reduction approach will play a demonstrative role in rural wastewater management.

Figure 2：Small Wastewater Treatment Facility with Solar Panels

Intelligent cloud platform information management systems. The introduction of an intelligent cloud platform information management system helps realize simultaneous online visual monitoring of distributed wastewater management systems. The intelligent cloud platform information management system is supported by mobile network technologies (e.g., mobile application and webpage terminal). Equipment management and fault alarming can be carried out under unattended modes. It provides a demonstration for future operation and management of distributed wastewater management.

Comparison of distributed and centralized systems. Comparison of distributed and traditional centralized wastewater management systems are summarized in Table 1.

Table 1: Comparison of Distributed and Centralized Wastewater Management Systems

Item	Type of Wastewater Management System	
	Distributed	**Centralized (Traditional)**
Location	Sujia Township, Sayu Town, and Leju Township in Zhaoyang District	
Capacity	400 m³/day	
Quality of treated wastewater	Meet Grade 1A standard	
Layout	28 small wastewater treatment facilities 84.3 km DN300 pipes	A WWTP in Sujia Township A wetland 25 pump stations 84.3 km DN300 pipes, 110 km DN100 pipes, and 62 km DN150 pipes
Construction cost	CNY71.75 million	CNY122.00 million
Operation and maintenance	Fully automatic computer management without special management	Need three people for manual maintenance
Operation cost	Electric fee: CNY240,900/year (power consumption of the 28 facilities: 55 kW; electric fee: CNY0.5/kWh) Maintenance cost: CNY500,000/year Total operation cost: CNY740,900/year	Electric fee: CNY766,500/year (power consumption of the WWTP: 25 kW; power consumption of the 25 pump stations: 150 kW; electric fee: CNY0.5/kWh) Maintenance cost: CNY650,000/year Staff salary: CNY108,000/year (CNY3,000/staff/month; 3 staff) Total operation cost: CNY1,524,500/year
Conclusion	Based on the above comparison, the distributed systems have many advantages and are more suitable for the area.	

CNY = Chinese yuan, DN = diameter nominal, m3 = cubic meter, km = kilometer, kW = kilowatt, kWh = kilowatt-hour, WWTP = wastewater treatment plant.

B. Animal Feces Management

One of major pollutant sources in rural areas is animal feces. Currently, animal feces pile in fields without any management. They pollute creeks and rivers when it rains and flow into the Yudong Reservoir. The project will install tanks with covers to collect animal feces and use them as fertilizer in farmlands after simple fermentation. This will not only solve the pollution problem, but also effectively promote reuse of animal feces as fertilizer.

Traditional animal feces collection tanks are made of concrete. The project will use tanks made seamlessly and integrally with glass fiber reinforced plastic, which are lighter, more corrosion-resistant, highly stronger, more economical, and easier for installation than traditional concrete tanks.

Animal Feces Pile **Manure Collection Tanks**

Figure 3: Animal manure pile and manure tank

C. Solid Waste Management

In rural areas, volume of solid waste in rural areas is much smaller than in urban areas; but cost of collecting and transporting solid waste is much higher than in urban areas due to scattered households and other buildings, and longer distance for transportation to treatment facilities. Solid waste management suitable for rural areas should be introduced. By reducing solid waste through garbage classification and introducing pyrolysis and gasification treatment, this project will effectively solve the problem of rural solid waste.

1. Garbage classification in rural areas

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Garbage classifications in the PRC is still at early stages even in urban areas. This project will introduce garbage classification in rural areas to reduce solid waste to be transferred to garbage treatment facilities. Under the project, garbage from households will be classified into three categories: recyclables, kitchen waste, and non-recyclables. The recyclables will be recycled, and kitchen waste will be composted and used as fertilizer. Only the non-recyclables will be transferred to treatment facilities.

Targets of garbage classification, by 2026, are as follow: (i) 20% of 30,890 households covered by the solid waste management will conduct garbage classification; (ii) garbage generation will be reduced from 0.70 kilograms/person/day before introduction of garbage classification to 0.46

kilograms/person/day; and (iii) amount of garbage transferred to and treated at the treatment facilities will be less than 1,456 tons/year. If more people involve in garbage classification, the environment benefits will be even more significant.

2. Innovative solid waste treatment technology

This project will adopt new garbage pyrolysis and gasification treatment technology. This technology can treat various kinds of solid waste, including domestic garbage; industrial garbage; agricultural and forestry garbage; solid waste from the WWTPs; and other hazardous solid wastes. Solid wastes with water content as high as 60% can be treated by this technology.

The core of garbage pyrolysis and gasification technology is to inhibit dioxins. The process of pyrolysis and gasification is carried out under hypoxic or anaerobic conditions, which reduces the generation of dioxin precursors. Moreover, valuable metals in solid wastes are not oxidized. Copper, iron, and other metals in solid wastes do not easily generate catalysts to promote dioxin formation. Harmful bacteria are destroyed by this process. The process flow diagram is shown in Figure 4.

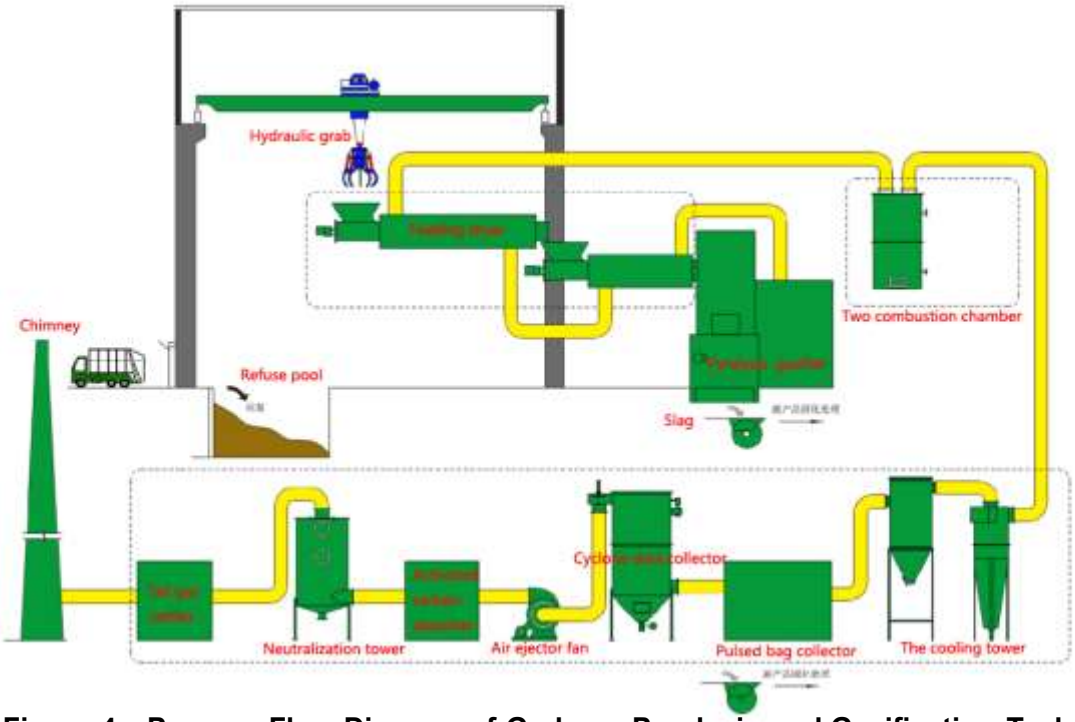


Figure 4: Process Flow Diagram of Garbage Pyrolysis and Gasification Technology

Comparisons of three solid waste treatment or disposal methods—landfill, incineration, and pyrolysis and gasification—are shown in Table 2.

Table 2: Waste Treatment Process Comparison

Item	Solid Waste Treatment or Disposal Methods		
	Pyrolysis and Gasification	**Incineration**	**Landfill**
Application	For small to medium volume of solid waste	For medium to large cities	For solid waste disposal

Item	Solid Waste Treatment or Disposal Methods		
	Pyrolysis and Gasification	**Incineration**	**Landfill**
	Widely used in rural areas	Capacity more than 300 tons/day in general	
Area for facility	Small 60–100 square meters (m^2)/ton	Medium to large 200–250 m^2/ton	Medium to very large 150–500 m^2/ton
Construction time	6–12 months	12–24 months	9–12 months
Suitable solid wastes	Plastics, fabrics, rubber, and other solid wastes	Combustible solid wastes	Not much restriction
Final disposal	Residue and fly ash (about 10%) need to be disposed of	Fly ash and slag need to be disposed of Hazardous waste needs special treatment	Not applicable (final disposal itself)
Degree of reduction	90%	90%	By natural decomposition of solid waste
Major environmental measures	Air emission control, noise control, fly ash disposal, residue disposal, and odor control	Air emission control, noise control, fly ash disposal, residue disposal, and odor control	Anti-seepage at the bottom of the landfill, daily coverage, landfill gas drainage, and leachate treatment
Construction cost	CNY200,000/ton–CNY300,000/ton	CNY400,000/ton–CNY600,000/ton	CNY150,000/ton–CNY300,000/ton
Operating cost	CNY50/ton–CNY80/ton	CNY80/ton–CNY120/ton	CNY40/ton–CNY60/ton
Technical characteristics	Short treatment cycle, small area, and good solid waste reduction	Large processing scale, good resource utilization, and good solid waste reduction	Simple operation and loan construction and operation costs
Main risk	Due to its small scale, if calorific value of a solid waste is low and/or its composition is complex, it easily causes unstable pyrolysis of solid wastes and substandard flue gas treatment.	Most of them are mixed garbage, and the smoke treatment is difficult for mixed solid waste. Dioxin formation and emission is a concern under unstable conditions. More stringent requirements are needed for operation and maintenance.	Damages of seepage prevention cause groundwater pollution. Accumulation of landfill gas poses a risk of fire and explosion.

In large- and medium-sized cities with large amount of solid waste, incineration technology is often adopted. Due to its small size, relatively simple operation, flexibility, and generally low construction and operating costs, pyrolysis and gasification technology is more suitable for rural areas with low solid waste production and underdeveloped economy. For this project, landfill technology cannot be adopted due to difficulty in selection of new landfill sites. Since solid waste

production is low, the economy is underdeveloped, and incineration technology cannot be adopted in the project area; and thus, pyrolysis and gasification technology are the most feasible option for the area.

D. Pilot Eco-Villages to Reduce Emission

1. Sponge countryside

In the pilot eco-villages, water-permeable pavement will be introduced to roads and squares; free spaces will be retained or revitalized; and local plant species, including vegetables and flowers, will be planted around houses, roadsides, and other spare lands to promote rain absorption and prevent pollutants from flowing into rivers.

2. Gabage classification, recycling, and reduction of resource use and waste stream

In the pilot eco-villages, garbage classification, recycling, and reduction of resource use and waste will be promoted through training to villagers and education of students, including phasing out of single-use plastics by replacing them with locally sourced reusable and compostable products.

3. Designated environmental supervision groups and cleaning teams

In each pilot eco-village, four villagers who are well-motivated to promote eco-village activities will be designated as environmental supervision group members. The environmental supervision groups will be involved in eco-village activities, including environmental awareness raising; ecological rewarding to selected households and cleaners; and publicity of the activities. In addition, six villagers per village will be hired to serve as cleaning team members. Given large share of elderly in the pilot eco-villages, the cleaning team members will likely be retired elderly villagers. The cleaning teams will maintain cleanliness of public spaces, roads, and green spaces.

E. Wetlands Construction to Reduce Nonpoint Source Pollution

1. New wastewater treatment technologies for artificial wetlands

In addition to traditional wastewater treatment through subsurface flow wetlands, new technologies, such as reed beds; ecological gravel beds; and drop aeration for artificial wetlands, will be used.

Wastewater treatment through wetlands with reed beds is a new technology which integrates physical, chemical, and biological functions; and effectively removes organic matters, total nitrogen, total phosphorus, and other pollutants in wastewater. Reed beds also can be wildlife habitats and improve ecosystems.

An ecological gravel bed is a biofilm process which uses gravel as a filler. It not only has the advantages of simple structure, low investment, and good water purification effect; but also improves water environment and ecology. Although a lot of research have been conducted on ecological gravel beds, improvement of low-pollution river water through ecological gravel beds to be conducted under the project is not common in the PRC. An ecological gravel bed is a relatively matured ecological technology and option for wastewater treatment.
Drop aeration is a process in which water falls from a height, stirs water surface, generates water

jump, and continuously updates the surface in contact with the air to transfer oxygen in the air to water; and thereby, oxygenate the water. Drop aeration not only controls water pollution and protects ecological environment; but also effectively reduces wastewater treatment cost and saves energy, effectively utilizing topographical features of mountainous and hilly areas in Zhaotong City. It is promising and has good social value, especially in Guizhou, Sichuan, and Yunnan provinces.

In the Xiaohebian Wetland in Shuimo Town of Ludian County and the Zhongheba Wetland in Longchu Town also of Ludian County, wastewater will be pre-treated through a sedimentation pond and reed bed before discharging into horizontal subsurface flow wetlands. In the design of Xinhe Wetland in Leju Township of Zhaoyang District, wastewater will be pre-treated through a grit chamber, aeration pond for drop aeration, and ecological gravel bed. The wastewater pre-treatment is for homogenization, sedimentation, aeration, and oxygenation, which reduce the burden of wastewater treatment on subsequent subsurface flow wetlands; and enhance wastewater treatment by wetlands.

2. Artificial wetlands in basic farmland

The project will introduce new artificial wetlands which can be constructed in basic farmlands where land use other than agriculture is not allowed. Farmlands will be reformed to wetland style farmlands by planting aquatic economic crops which have water purification function. The wetlands will be constructed in accordance with related regulations on the protection of basic farmlands.

Figure 5: Sample of Wetlands Constructed in Basic Farmland

F. Establishment of Quantifiable Soil and Water Conservation Model

Quantitative benefits of afforestation on soil and water conservation have been studied in the northern and northwestern loess plateau areas of the PRC; but less in the southern, especially in the southwestern plateau areas. This project will contribute to quantify these benefits.

For establishment of quantifiable soil and water conservation model, four afforestation patterns and bare ground with 15-, 25-, and 35-degree slopes (15 patterns in total) were selected. For

each pattern, four monitoring plots were selected (60 monitoring plots in total). Soil erosion volume per unit area and unit time and water retention volume per unit area will be estimated using an existing model. Based on comparison between the estimated volumes and data actually measured at the 60 monitoring slots, the model will be revised. It is expected to take about 10 years to get data adequate to revise the model. However, tentatively improved model will be presented by the project completion.

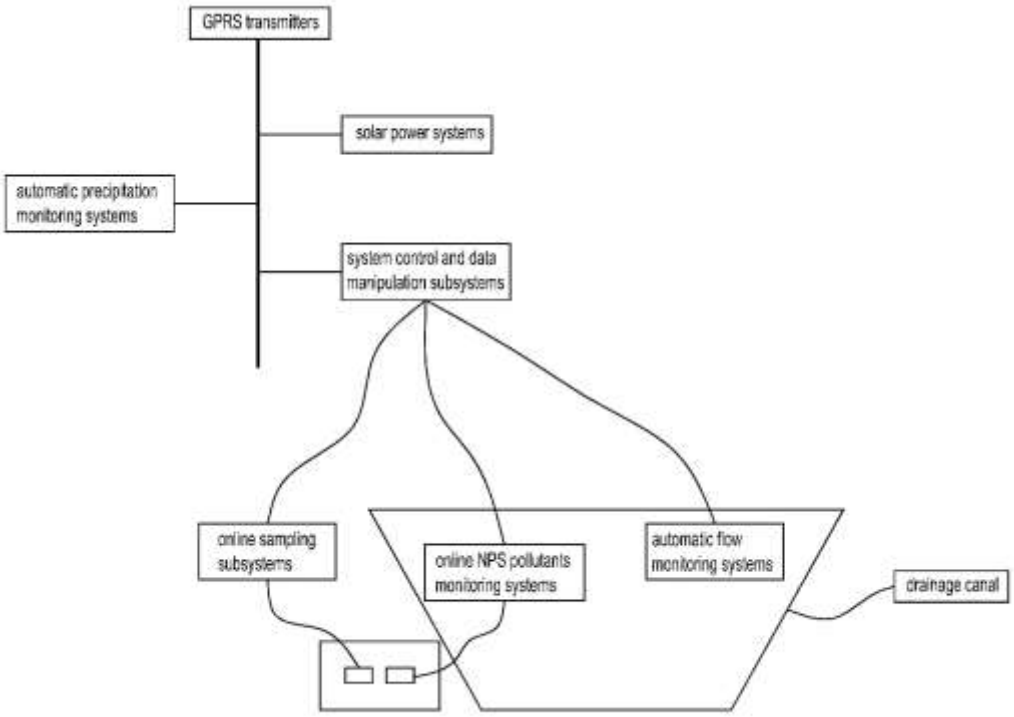
Table 2: Soil Erosion and Water Retention Capacity by Forest Type (Example)

Factor	Type of Forest or Land					
	Barren Hill	**Coniferous Forest**	**Broad-Leaved Forest**	**Shrub Woods**	**Coniferous and Broad-Leaved Mixed Forest**	**Tree-Shrub Mixed Forest**
Soil erosion volume (ton/square kilometer/year)	2,500.00	134.71–206.51	55.58–111.16	1.79–24.48	76.35–119.02	3.83–58.24
Water retention capacity (ton/hectare)	1,605.86	1,787.80	1,829.67	1,871.54	1808.74	1,850.61

G. Promotion of Low-Emission Agriculture

1. Monitoring systems of nonpoint source pollution

A monitoring system for the nonpoint source (NPS) pollution will be established in the Highland Characteristic Agricultural Demonstration Zone in Longshui Town of Ludian County. Main pollutants in the demonstration zone, such as nitrogen and phosphor, will be monitored in a gridded platform. Pollutants from fertilizer, pesticides, and run-off in different cropping patterns will be monitored to compare effects of the NPS pollution reduction activities. The monitoring systems includes seven systems: general packet radio services transmitter, solar power system, automatic precipitation monitoring system, system control and data manipulation subsystem, online sampling subsystem, automatic flow monitoring system, and online NPS pollutants monitoring system (Figure 6).



GPRS = general packet radio services, NPS = nonpoint source.

Figure 6: Structure of Nonpoint Source Pollution Monitoring System

2. Green and organic apple brand

In the Zhaotong Featured Apple Industry Demonstration Point in Sayu Town of Zhaoyang District, (i) integration of water and fertilizer will be conducted to reduce fertilizer use; (ii) organic and special fertilizer application will be increased; and (iii) a green and organic apple brand will be established to increase famers' motivation to reduce chemical fertilizer use.

3. Ecological drainage ditch

Aquatic plant species which absorb nitrogen and phosphor (e.g., *Canna, Rhizoma Scirpi, Myriophyllum Elatinoides, Hydrocotyle Vulgaris*, and Common Rush) will be planted in geogrids or concrete grids in ecological drainage ditches. Content of nitrogen and phosphor in water will be reduced through the ecological drainage ditches.

4. Recycling of crop residues and animal manure

In the Breeding and Recycling Agriculture Demonstration Point in Sujia Township of Zhaoyang District, maize grain and crop residues will be used as feedstuffs to pigs; pig manure will be used to produce organic fertilizer; and the produced organic fertilizer will be used for farming to reduce chemical fertilizer use, and realize circular agriculture and zero emission.

H. Establishment of River Protection Model

1. Ecological embankments

Under the project, ecological protection approach has been adopted for improvement of river embankments. The ecological embankments naturally absorb the NPS pollution and purify water flowing into the rivers.

Figure 7: Existing Embankments in Project Area

Figure 8: Samples of Ecological Embankments

2. River protection model

Monitoring of the rivers is also needed to protect the rivers from pollution. The project will establish an intelligent cloud platform river information management system. This system will automatically send data on rivers to mobiles of staff responsible for river management.

The project will also construct three water quality monitoring stations, four water level and video monitoring stations for rivers, seven rainfall stations for main rivers, and 72 360-degree video monitoring stations at the artificial wetlands, garbage pyrolysis facilities, the WWTP, small wastewater treatment facilities, and pilot eco-villages. By integrating these monitoring stations and an existing irrigation area information system, a smart water integrated management platform will be established.

The intelligent cloud platform river information management system and the smart water integrated management platform will enable real-time monitoring and actions in the event of water quality deterioration. In addition, related institutional development will be conducted, particularly the system and platform will be used to strengthen the existing river chief system.

I. Establishment of Eco-Compensation Mechanisms

Under the project, an existing horizontal eco-compensation agreement between the Ludian County Government and the Zhaoyang District Government will be implemented; and new town- and township-level horizontal eco-compensation mechanisms will be established and implemented. For the implementation of these agreements, water quality monitoring will be conducted using the water quality monitoring stations constructed under the project or in other ways to judge whether or not water quality targets set in the agreements were achieved, which will be the basis for compensation.

An eco-compensation fund will be also established to provide grants to relevant government agencies and private companies for (i) wastewater management, solid waste management, activities for pilot eco-villages, operation and maintenance of the constructed wetlands, compensation for the farmland-to-forest conversion, and promotion of low-emission agriculture under Output 1 of the project; (ii) operation of the river protection model established under Output 2 of the project; (iii) implementation of the horizontal eco-compensation mechanisms under Output 3 of the project; and (iv) management of the eco-compensation fund, which will not finance any civil works.[1] The fund will be initially supported by the governments and the Asian Development Bank,[2] with the longer-term goal of diversifying the funding sources and collecting more funding from beneficiaries[3] to improve sustainability of the fund; and strengthen direct linkage between upstream eco-service providers and downstream beneficiaries, following the principle of "those who benefit should compensate."[4] An eco-compensation fund management committee (EFMC) will be established in the Zhaotong City Government.[5] The EFMC will conduct screening of activities proposed for financing from the fund in accordance with an environmental and social management system. The Yudong Reservoir Water Resources Protection Committee Office in the Zhaotong City Government, an implementing agency of the project, will manage the fund following decisions of the EFMC.[6] The Zhaotong City Finance Bureau will open and manage the account to be used for the fund, following decisions of the EFMC.

More details in the eco-compensation mechanisms are provided in the supplementary document on the Eco-Compensation Mechanism for the Sayu River Basin.[7]

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1 Private companies will operate the wastewater treatment plants and conduct solid waste management in Zhaoyang District and Ludian County based on their contracts with the ZDG and LCG.

2 Chinese yuan (CNY) 8 million from the ZCG, CNY5 million from the ZDG, CNY2 million from the LCG, and CNY2 million of water resources utilization fee from the downstream Baoho hydropower station will be contributed to the eco-compensation fund every year from 2023. The ADB loan of about $5 million will be added to the fund during the project.

3 Beneficiaries will include downstream water and hydropower users and business sector.

4 In the near term, adding surcharges to water and hydropower fees is not politically or economically feasible.

5 The chair of the EFMC will be the vice mayor of the ZCG; and the members will be the Deputy Directors General of about 10 ZCG agencies, including the Development and Reform Committee; Finance Bureau; and Environment and Ecology Bureau.

6 The 15 full-time staff of the Yudong Reservoir Water Resources Protection Committee Office, who manages an existing fund for ecological restoration and remediation, will manage the new eco-compensation fund.

7 Eco-Compensation Mechanism for the Sayu River Basin (accessible from the list of linked documents in Appendix 2 of the *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the People's Republic of China for the Yunnan Sayu River Basin Rural Water Pollution Management and Eco-Compensation Demonstration Project* [ADB. 2020. Manila]).

II. KNOWLEDGE DISSEMINATION

Experiences and knowledge gained on rural water pollution management and eco-compensation through this project can be replicated to other small tributaries in the upper and middle reaches of the Yangtze River that account for 80% of the total wastewater, and even to other key river basins in Asia and the Pacific. Adequate consulting services will be provided to help in the replication through workshops, publications, disclosure of project information on website, submission of papers to academic societies, application for a model project for eco-civilization, application for award programs, etc.