# ECONOMIC ANALYSIS

## A. Introduction and Economic Rationale

1. The economic analysis is undertaken for the project components, including (i) township and village wastewater, agricultural nonpoint source protection, and township and village solid waste management under the pollution control component; (ii) Chukou and Yangdongxia water supply systems; and (iii) river course rehabilitation, aquatic ecosystem rehabilitation, wetland protection, soil erosion control, and public forest protection and bamboo forest improvement under the ecosystem rehabilitation and management component. The analysis follows the relevant guidelines of the Asian Development Bank (ADB), which require least-cost and cost–benefit analyses that evaluate the components using with- and without-project scenarios.[1] The analysis is carried out over 30 years considering the expected life of the facilities. Costs and benefits are set out in discounted cash flows to calculate the economic internal rate of return (EIRR) with the real opportunity cost of capital assumed at 12% as hurdle rate.

2. The environmental protection and integrated improvement of Dongjiang Lake is a direct response to the master plans of Hunan Province, Chenzhou Municipality, and Zixing City. The project will generate the following economic benefits through the various subcomponents: (i) improved sanitation and cleaner lake environment; (ii) increased incomes from fruit tree, fish, and bamboo production; (iii) improved access to clean water supply; (iv) avoided damage to personal life and property by flood and forest fire; and (v) reduced soil erosion. The project supports the national government's Yangtze River Economic Belt Initiative released in September 2014 to construct an ecological ecosystem corridor along the river by improving watershed management, water pollution control and prevention, and ecological rehabilitation.[2] It conforms with ADB's Water Operational Plan, 2011–2020, to improve water supply and sanitation services, and to promote integrated water resources management.

## B. Least-Cost Analysis of Project Alternatives

3. The least-cost analysis considers feasible options for each subproject from the perspective of engineering and technical criteria, including variations in construction sites, planning horizon, and demand and cost of design. For the wastewater subcomponent, the choice of biofilm (contact oxidation) results in CNY0.36 million savings against the membrane bioreactor treatment processes; for the solid waste disposal method, the transfer station preferred over carbonization pyrolysis results in savings of CNY3.68 million; for the water supply treatment process, the inclined pipe sedimentation tank over horizontal sedimentation results in savings of CNY80.71 million; for the choice of river revetment, Renault pad and grass over precast concrete blocks results in savings of CNY1.95 million; for soil erosion and public forest, planting mixed tree species over single-tree species results in savings of CNY0.84 million; for bamboo forest improvement, the reformative model (cave soil preparation supported by tree planting and bamboo ditch) over the traditional method (full soil preparation only) results in savings of CNY1.9 million; and for wetlands improvement, the artificial method using horizontal underflow over surface flow results in savings of CNY2.91 million. The application of least-cost options results in overall cost savings amounting to CNY92.35 million.

## C. Cost–Benefit Analysis

[1] ADB. 1997. *Guidelines for the Economic Analysis of Projects*. Manila; ADB. 1999. *Handbook for the Economic Analysis of Water Supply Projects*. Manila.

[2] The State Council of the People's Republic of China. 2014. Guide on Promoting the Development of the Yangtze Economic Belt. http://www.gov.cn/zhengce/content/2014-09/25/content_9092.htm

## 1. Economic Costs

4. Economic costs are converted from financial costs expressed in mid-2015 terms. Tradable costs are converted using a shadow exchange rate factor of 1.08 calculated using the available trade data of the People's Republic of China, non-tradable goods at 1.0, and unskilled labor at 0.8. Subcomponent costs consist of (i) investment cost, including civil works and materials and equipment, engineering, land, and physical contingencies; and (ii) annual operation and maintenance (O&M) costs, including labor wages, treatment, energy, repair and maintenance, and administration.

5. **Township and village wastewater.** The township subproject will finance six wastewater treatment plants (WWTPs) designed to treat 2,000 cubic meters ($m^3$)/day, and pipeline network of 38.1 kilometers. The converted economic investment cost is CNY42.60 million. The annual economic O&M cost totals CNY1.37 million. The village subproject will finance packaged WWTPs in strategic locations serving households in village communities. The economic investment cost amounts to CNY110.76 million. The economic O&M cost of the packaged WWTPs is community-based, thus expected to be minimal, requiring CNY0.15 million annually.

6. **Agricultural nonpoint source pollution control.** The subproject will involve (i) soil testing and the promotion of formulated (green) fertilizers to replace the use of chemical-based fertilization, and (ii) the promotion of physical and biological prevention and control of crop pests. The economic investment cost is CNY77.48 million. The recurrent costs include tree management and administrative expenses amounting to CNY7.83 million annually.

7. **Solid waste management.** The subproject will finance seven transfer stations, equipment and vehicles at townships, and facilities such as garbage bins and mechanized collection wagons in villages. The economic investment cost is CNY 57.52 million. The annual economic O&M costs, including labor, power and fuel, chemicals, and maintenance expenses, amount to CNY 8.01 million.

8. **Chukou and Yangdongxia water supply.** The Yangdongxia subproject will finance a treatment plant with capacity of 20,000 $m^3$/day and 700 kilometers of distribution pipelines. The economic capital cost amounts to CNY266.66 million. The annual economic O&M costs amount to CNY4.35 million. The Chukou subproject involves source development, and transmission and distribution networks in urban and rural communities. The economic capital cost amounts to CNY5.47 million, with annual O&M costs of CNY0.57 million.

9. **River course rehabilitation.** The river management subproject will finance rehabilitation works on five major rivers. Works will involve comprehensive realignment and renovation, including dredging, revetments, grassing, and riparian greening. The economic cost of capital amounts to CNY91.28 million. The annual O&M cost is CNY2.72 million.

10. **Aquatic ecosystem rehabilitation.** The subproject will finance the construction of fish-breeding cages, breeding ponds and spawning pools, fish fry-rearing ponds, and nursery plant transformation; the construction of an aquaculture technology center and monitoring stations; and purchase of monitoring vehicles, and management facilities. The economic investment cost is CNY103.21 million. The annual O&M cost is CNY3.10 million.

11. **Wetlands protection.** The subproject will include green channel revetment construction, wetland plant community restoration, equipment and facilities for wetlands cultural education,

research and monitoring, and science education. The economic cost is CNY172.34 million and the O&M cost is CNY7.50 million.

12. **Forest and soil protection.** The subproject will finance the acquisition of forest fire prevention facilities and the biological forest fire prevention belt, and the purchase of fire protection equipment and vehicles. The economic investment cost is equivalent to CNY204.03 million. The annual subproject O&M cost is CNY3.40 million.

13. **Bamboo forest improvement.** The subproject will finance bamboo plant seeding, fertilizers, and afforestation activities. The economic investment cost is equivalent to CNY68.51 million. The annual economic O&M cost is CNY1.08 million.

### 2. Economic Benefits

14. The project will generate a variety of benefits, including improved sanitation and a cleaner environment; reduced health risks in drinking water; avoided flood and forest fire damage; increased fruit tree, fish, and timber production; water treatment; and resource cost savings. A contingent valuation survey was conducted to solicit households' willingness to pay for improved wastewater, solid waste, and water supply services.

15. **Township and village wastewater.** By 2020, the WWTPs will serve about 12,500 residents in townships, and 96,300 residents in villages. The benefits for wastewater draw from new treatment facilities that will ensure ecological protection of the lake and lakeshore areas, health benefits, and overall environmental safety. The survey results show willingness to pay for services at CNY1.87/$m^3$.

16. **Agricultural nonpoint source pollution control.** The main benefit is increased production revenues from the application of green pesticides on tangerine fruit trees with the project against the use of commercial spray pesticides without the project. The adoption of green prevention reduces the costs of spraying and materials by CNY3030/hectare (ha), and ensures a higher yield and better quality fruits. The without-project method results in tangerine production of 30,000 kilograms (kg)/ha, priced at CNY3.00/kg, while with-project output increases to 30,900 kg/ha, priced at CNY3.20/kg.

17. **Solid waste management.** The main economic benefit is derived from the willingness to pay for the proposed solid waste services. The application of waste compression transfer stations will contribute to the beautification of the environment, eliminating and/or limiting secondary pollution, including the breeding of flies and other vectors. Improvements promote the efficiency of vehicle-mounted waste collection and cleaning activities, and lighten workers' load. The survey respondents signified willingness to pay higher than the prevailing solid waste fees in areas outside subproject coverage, where service exists. The estimated willingness to pay, based on the survey, is CNY191/ton.

18. **Chukou and Yangdongxia water supply.** The subproject will reduce the economic cost of obtaining water from existing supply sources, replace private water supplies currently consumed (non-incremental demand) by domestic and non-domestic users, and enable users to increase consumption levels (incremental demand). It is expected that the average per capita daily consumption of 60–100 liters for rural and 70–140 liters for urban consumers in 2015 will increase initially and eventually to about 150–220 liters with the project. As the economic price of the project water at CNY1.58/$m^3$ is cheaper than the costs associated with obtaining from

existing sources, a net economic gain to users will occur.[3] Resource cost savings are estimated by multiplying the quantity of non-incremental water by the economic supply price. Benefits from incremental water consumption are estimated by multiplying new consumption volumes by the willingness-to-pay price, calculated at CNY 1.45/$m^3$.

19. **River course rehabilitation.** The subproject will provide protection against floods up to a minimum 10-year return period along the five rivers in Zixing City. The main economic benefit of avoided losses attributable to improved flood protection is estimated using available estimates of flood return periods and damage data from historical floods.[4] The economic loss related to farmland amounts to CNY400/*mu*, based on the water resources bureau estimates of farmland yield loss and/or decline in historic inundation events of the five rivers. The economic loss related to population focuses on the cost for repair or restoration of physical property (houses, shops, factories, etc.) in the inundation area.

20. **Aquatic ecosystem rehabilitation.** Subproject ecological benefits derive from (i) water purification and general improvement in water quality through fish breeding to restore natural amounts of fish species in Dongjiang Lake, (ii) enrichment of fishery sources through fish breeding and artificial releasing based on new technological practices, and (iii) livelihood improvement for fisherfolk and promotion of recreational fishing through natural fishing methods. By breeding and releasing specific kinds of fish, the benefits of maintaining lake water quality and biodiversity of fish species will result in commercial fish production and ultimately profits. Benefits are calculated from the net savings of applying traditional treatment of nitrogen and phosphorus in the without-project scenario against the with-project cost of using the natural method of seeding the lake with special species and applying artificial releasing of fish to maintain appropriate ecological thresholds. The use of the tested natural proliferation and artificial control method not only increases fish yield, but also brings down the production cost, resulting in higher net earnings to fisherfolk and benefits and satisfaction for consumers.

21. **Wetlands protection.** The subproject will greatly reduce pollutants in the water environment along the lake area and improve the ecological environment by protecting the 166 ha of wetlands in the region, thereby negating unnecessary large expenditures for lake water treatment. With the project in place, a natural barrier will be created to reduce land-sourced pollution from chemical oxygen demand, total nitrogen, and total phosphorus by 15%–20%; and ensure the upgrade of all water quality indicators to above Class III. Thus, the project will produce cost savings in lake water treatment estimated at CNY0.03 per square meter ($m^2$)/day compared with the WWTP treatment cost of CNY0.05–CNY0.08/$m^2$/day. Likewise, with the project, the water quality of Dongjiang Reservoir will improve and the risks of pollution-induced economic loss will be mitigated or erased. The price of lake water as a supply source will be cheaper, with conservation measures arising from artificial wetland construction by an estimated CNY0.02/$m^2$/day. This would be equivalent to CNY16.36 million in treatment cost savings, and CNY12.12 million in resource cost savings.

22. **Forest and soil protection.** The subproject will lead to soil and water conservation cost savings and avoided damage costs to timber resulting from frequent forest fires. The improved forest area will cover 14,666 ha, with 1,000 ha impacted by forestation and 13,666 ha by replanting activities. Soil erosion without forest condition amounts to 33.19 tons/ha, while with forest condition, 1.35 tons/ha, so soil conserved with forest condition is 31.84 tons/ha, equivalent to a total volume of 467,000 tons in the improved area. The benefit draws from

[3] Converted from the financial selling price of CNY1.81/$m^3$.

[4] Damage data are updated to account for inflation and growth of vulnerable assets caused by urban development. The value of vulnerable assets is conservatively assumed not to increase in real terms over the forecast period.

annual savings in dredging costs of CNY50/ton multiplied by this volume or CNY23.35 million. Additionally, under forest conditions, average annual rainfall is 1,538 $m^3$. The history of evapotranspiration in the area shows a 53% rate, so the annual volume of water conserved in the improved area amounts to 7,241 $m^3$. Priced at CNY1.50/$m^3$, the annual water conservation benefit amounts to CNY10.86 million. Of the total forest area of 13,666 ha, about 27 ha would be affected by yearly fire incidents. Timber volume in these areas is estimated at 33.6 $m^3$/ha. At CNY1,100/$m^3$, the total avoided fire loss would be CNY0.99 million annually. The aggregate subproject annual benefits amount to CNY35.2 million.

23. **Bamboo forest improvement.** The subproject derives its benefits from the net improvement in the output of the low-yielding Moso bamboo forest, which will result in higher revenues for farmers. The area covers 2,595 ha. Interventions will increase annual bamboo timber production from 2.1 tons/ha to 7.3 tons/ha. Bamboo shoot production will also increase from 0.56 tons/ha to 1.3 tons/ha. Revenue increase from bamboo timber and shoot production will amount to CNY16.28 million, netting off the increased cutting and tending costs.

## D. Economic Internal Rate of Return

24. The combined base case EIRR for the entire project is 14.5%. The estimated benefits of the project are considered conservative since many benefits are identified but not quantified in the analysis. The sensitivity analysis tested the effects of adverse changes in key parameters. The sensitivity analysis finds that the project remains economically viable despite a 10% increase in capital cost (at 13.1%), a 10% increase in O&M costs (at 14.1%), a 10% decrease in benefits (12.6%), a combined 10% increase in costs and decrease in benefits (at 11.0%), and a 1-year implementation delay (at 12.3%). The switching values indicate the project is viable until the capital cost increases by 18.2% or benefits decrease by 13.1%. The table presents the summary EIRRs by component and subprojects.

**Table: Summary Economic Internal Rate of Return and Sensitivity Analysis**

| Item | EIRR (%) | ENPV (CNY million) | Sensitivity Indicator | Switching Value (%) |
|---|---|---|---|---|
| **Pollution Control Component** | 15.1 | 64.87 | | |
| Wastewater—Town and Village | 13.7 | 19.11 | | |
| Agricultural Nonpoint Source | 21.9 | 27.96 | | |
| SWM—Town and Village | 14.6 | 17.80 | | |
| **Urban and Rural Water Supply** | 13.1 | 16.18 | | |
| Yangdongxia Water Supply | 12.7 | 9.29 | | |
| Chukou Water Supply | 31.5 | 6.89 | | |
| **Ecosystem Rehabilitation and Management** | 14.8 | 75.70 | | |
| River Course Rehabilitation | 13.9 | 7.40 | | |
| Aquatic Ecosystem Rehabilitation | 15.8 | 17.08 | | |
| Wetlands Protection | 15.0 | 19.48 | | |
| Forest and Soil Protection | 13.9 | 15.09 | | |
| Bamboo Forest Improvement | 15.7 | 16.65 | | |
| **Overall Project** | | | | |
| (a) Base case | 14.5 | 156.75 | | |
| (b) Capital cost increased by 10% | 13.1 | 77.17 | 5.48 | 18.2 |
| (c) O&M cost increased by 10% | 14.1 | 132.13 | 1.60 | 62.5 |
| (d) Benefits decreased by 10% | 12.6 | 36.88 | 7.63 | 13.1 |
| (e) Construction delay by 1 year | 12.3 | 18.15 | 6.85 | 14.6 |
| (f) Combined (b), (c), (d) | 11.0 | (67.31) | 13.97 | 7.2 |

( ) = negative, EIRR = economic internal rate of return, ENPV = economic net present value, O&M = operation and maintenance, SWM = solid waste management.
Source: Asian Development Bank estimates.