A. Reservoir Rehabilitation and Management in the People’s Republic of China

1. The People’s Republic of China (PRC) has been building dams for more than 2,500 years and now has 87,085 reservoirs—the most in any country in the world. These reservoirs have been important in flood control, irrigation, hydropower generation, and water supply, and in the PRC’s rapid economic development (the economy grew by about 10% per year on average from 1978 to 2008). The reservoirs have a total storage capacity of about 554 billion cubic meters (m^3), about one-sixth of the total yearly runoff nationwide, and control an irrigation area of about 16 million hectares (ha), about one-third of the country’s total irrigation area. Their total generation capacity of about 70 million kilowatts is about one-third of the total national power generation. The reservoirs provide about 500 billion m^3 of water supply yearly, about 20 billion m^3 of this for household use. In 1998, 1,335 large and medium-sized reservoirs in the PRC stored about 53 billion m^3 of floodwater and protected more than 200 cities and 2.3 million ha of farmland from flooding, reducing the number of people who fell victim to flooding by 27.4 million. Many small reservoirs are mainly found in mountainous and hilly areas, providing valuable water to local people and agriculture and playing important roles in people’s lives and in poverty reduction.

2. About 90% of the reservoirs in the PRC were built in 1958–1976, during the Great Leap Forward and the Cultural Revolution, and therefore have been used for 30–50 years. The construction was generally done very rapidly, using outdated and low technical standards, with inadequate plans, surveys, designs, and construction. Many water-retaining dams and equipment are damaged and need to be repaired and strengthened. The reservoirs are largely beset by problems, such as poor flood control, serious water leakage, obsolete facilities, weathered equipment, lack of monitoring facilities, and inadequate maintenance and management, and do not meet modern standards of safety against flooding and earthquake.

3. According to the Safety Assessment Methods for Dams and the Guidelines on Dam Safety Assessment, reservoirs in the PRC fall into three safety classes. A total of 37,032 reservoirs (43%) are in the class III (most unsafe) category. Class III reservoirs are at risk of potential failure and thus pose a threat to people’s lives and property downstream. In 1954–2007, at least 27,876 people were killed when 3,503 reservoirs (an average of 65 every year) collapsed. In 1993, the Gouhou reservoir in Qinghai Province collapsed, killing 320 people and causing enormous economic loss. In 1995, 2001, and 2005, reservoirs in Hubei, Sichuan, and Yunnan provinces collapsed and killed 76 people, and caused crippling damage to the local economy. There are 115 large and 306 medium-sized especially unsafe reservoirs that could cause serious damage to downstream areas, where about 146 million people live.

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1 This summary is based on ADB. 2010. Risk Mitigation and Strengthening of Endangered Reservoirs in Shandong Province. Consultant’s final report. Manila (TA 7270-PRC).
2 The data are as of the end of 2006. Not included are reservoirs in Hong Kong, China; Macau, China; and Taipei, China.
3 A large reservoir has a storage capacity of at least 100 million m^3.
4 A medium-sized reservoir has a storage capacity of 10–100 million m^3.
5 A small reservoir has a storage capacity of 0.1–10 million m^3.
8 The data are as of the end of 2006. The number of class III reservoirs is changing as class III reservoirs are rehabilitated and new reservoirs enter into this category. The actual flood control capacity of class III reservoirs is below current national standards. The reservoirs do not work as designed and present a high safety risk.
4. The storage water level of many reservoirs was originally designed to suit the hydrometeorological features of the watershed and water demand downstream. Now, however, many endangered reservoirs do not store water up to the design level because of water leakage, the instability of water-retaining dams, and inadequate spillway capacity for the emergency discharge of rapidly rising floodwaters. As a result, these endangered reservoirs cannot control floods, supply irrigation water, generate hydropower, or provide year-round supply of household water to users. Strengthening these reservoirs will increase water supplies at less cost and with less adverse impact on the environment and people than building new reservoirs. Strengthened reservoirs will also have potentially positive benefits downstream, especially on the environment, by increasing reservoir releases for environmental flow. It is estimated that the recently rehabilitated 1,346 reservoirs in the PRC have increased the storage capacity by 500 million m$^3$, equivalent to the increase in storage capacity from the construction of 540 new medium-sized reservoirs. The cost of reservoir rehabilitation per cubic-meter increase in storage capacity (CNY2–CNY3) is lower than the cost of new reservoir construction (CNY6).

5. The government has accorded high priority to strengthening endangered reservoirs. In 2001, the Ministry of Water Resources formulated the National Reservoir Strengthening Program to advance reservoir strengthening with financial assistance from the government. The first phase of this program has been successfully completed, and 1,346 reservoirs are now in operation at design capacity. The second phase began in 2003 with the objective of strengthening 2,112 class III reservoirs. To further expedite the rehabilitation of unsafe reservoirs, the third phase of the program was prepared in October 2007 for a total of 6,240 reservoirs, including those uncompleted in the second phase.

6. The National Reservoir Strengthening Program will be completed during the period of the PRC’s 11th Five-Year Plan (2006–2010). However, reservoir rehabilitation will continue even after the national program, since more than 30,000 unsafe reservoirs still have to be rehabilitated and current class I and II reservoirs, which are not included in the national program, are expected to deteriorate further and need urgent rehabilitation. In addition, reservoirs rehabilitated under the national program will have to be appropriately operated, maintained, and managed for safe and effective use; otherwise, the reservoir rehabilitation would have been futile. To address these issues, sustainable reservoir rehabilitation and management models should be established in a province where reservoir safety issues are quite serious, such as Shandong Province, and successful models should be replicated throughout the PRC.

B. Reservoir Rehabilitation and Management in Shandong Province

7. Shandong Province is along the east coast of the PRC, downstream of the Yellow River. The total area of 157,100 square kilometers includes both peninsular and inland areas. The Shandong peninsula extends into the Bo Sea and the Yellow Sea across the Liaodong peninsula. The inland area borders Anhui, Hebei, and Jiangsu provinces from north to south. The total population is 94.2 million, the second largest in the PRC. The topography of Shandong Province is quite complex, and could be divided into nine different types, including mountain areas, hilly area, terrace area, basin area, plains, and Yellow River delta. The mountain areas occupy about 15.5% of the total areas, hilly areas 13.2%, plains 55%, and rivers and lakes 1%. The average temperature is 11°C–15°C, and average rainfall is 500–800 millimeters. There are frequent natural disasters, such as floods and droughts, in the province.

8. Shandong Province is one of the fastest-developing provinces in the PRC, but it is also a province where water scarcity is most serious, with water resources per capita of only about
one-sixth of the national average. In addition, Shandong Province suffers the problem of saltwater intrusion into coastal catchments, which reduces the usability of water resources. Economic development in recent years is also increasing the demand for water supply. The number of reservoirs in Shandong Province—5,820—is the fifth largest in the PRC.!\(^9\)

9. Reservoir safety (see table) is a great concern. Out of the 5,820 reservoirs in Shandong Province, 4,114 (71%) are in the class III (most unsafe) category (footnote 9). This proportion, the highest in the PRC, is much higher than the national average of 43%. Reservoirs collapsed 255 times and killed 225 people in Shandong Province in 1966–2008. The reservoir collapse ratio of 4.38% is much higher than the national average of 4.02%.

**Indicators of Reservoir Safety in Shandong and Other Provinces**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Hunan</th>
<th>Jiangxi</th>
<th>Shandong</th>
<th>Sichuan</th>
<th>PRC!(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of reservoirs</td>
<td>13,300</td>
<td>9,783</td>
<td>5,820</td>
<td>6,717</td>
<td>87,085</td>
</tr>
<tr>
<td>Number of class III reservoirs</td>
<td>7,030</td>
<td>3,488</td>
<td>4,114</td>
<td>1,008</td>
<td>37,032</td>
</tr>
<tr>
<td>Ratio of class III reservoirs to total reservoirs (%)</td>
<td>52.9</td>
<td>35.6</td>
<td>70.7</td>
<td>15.0</td>
<td>42.5</td>
</tr>
<tr>
<td>Number of reservoirs that have collapsed</td>
<td>285</td>
<td>170</td>
<td>254</td>
<td>400</td>
<td>3,503</td>
</tr>
<tr>
<td>Reservoir collapse ratio (%)</td>
<td>2.1</td>
<td>1.7</td>
<td>4.4</td>
<td>6.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

PRC = People’s Republic of China.

\(!^a\) Excluding reservoirs in Hong Kong, China; Macau, China; and Taipei, China.


10. Shandong Province recognizes the urgent need for reservoir rehabilitation. A total of 137 class III reservoirs in the province have been included in the National Reservoir Strengthening Program. Shandong Province has also formulated its own plan for rehabilitating unsafe reservoirs that are not included in the national program, using its own funds.\(^10\) However, the province is facing technical and financing difficulties, and has realized that it will take a longer time to rehabilitate all unsafe reservoirs. The province has also recognized the importance of properly managing the rehabilitated reservoirs for their safe and effective use for economic development. Shandong Province needs a methodology for efficiently and effectively rehabilitating a large number of unsafe reservoirs within a limited budget, and a plan for properly managing the rehabilitated reservoirs.

C. Rationale

11. The People’s Government of Shandong Province has requested a loan from the Asian Development Bank (ADB) to support the establishment of sustainable reservoir rehabilitation and management models through the rehabilitation, management, monitoring, and evaluation of model reservoirs. ADB’s assistance will enable Shandong Province to gain access to international expertise and experience in reservoir rehabilitation and management. The established model will be used not only in Shandong Province but also in other provinces of the PRC where reservoir safety is of great concern.

12. The proposed project will contribute to integrated water resources management (IWRM) by establishing sustainable reservoir rehabilitation and management models, and is therefore line with the priorities of ADB’s water policy in promoting IWRM. The proposed project is also in

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\(^9\) The data are as of the end of 2008.

line with the country partnership strategy (2008–2010) for the PRC, which prioritizes environmental sustainability through more effective natural resources management, and supports the government’s objectives in the water sector.11

13. The project will have a direct positive impact on poverty reduction and the environment since it will (i) mitigate the potential risk of failure of reservoirs and protect the lives, property, and livelihoods of people living on the flood plains downstream of the reservoirs, where poverty incidence is high; (ii) provide more water for agriculture and household use to the poor living downstream of the reservoirs; and (iii) improve the quality of reservoir releases, especially in the dry season, to sustain the wetlands and the health of flora and fauna, maintain fisheries, preserve water quality, and improve groundwater resources. The project will also have a positive impact on poverty reduction and the environment upstream through watershed management as part of IWRM.

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Problem Tree for Agriculture and Natural Resources (Endangered Reservoirs)

1. Low economic and social development
   - High poverty incidence
     - Loss of people’s lives and property
     - Low investment in improving livelihood
     - Low investment by business entities
     - Low standards for designs, construction, and management
     - Lack of methodologies for efficient rehabilitation planning
     - Lack of funds
     - Low capacity of staff

2. Endangered reservoirs
   - Reservoir failures
   - Inadequate flood control
     - Lower water supply to domestic use than planned
     - Lower hydropower generation than planned
     - Lower water supply to industrial use than planned
     - Lower irrigation water than planned
     - Low investments to irrigation system improvements

3. Low planting output value
   - Reservoirs not meeting modern standards for safety
     - Inadequate surveys, plans, and designs
     - Rapid construction with poor management and low quality materials
     - Low standards for designs, construction, and management
     - Lack of funds
     - Low capacity of staff
     - Lack of methodologies for efficient rehabilitation planning
     - Lack of practical technical guidelines for rehabilitation

### Sector Results Framework (Endangered Reservoirs, 2010–2015)

<table>
<thead>
<tr>
<th>Country Sector Outcome</th>
<th>Country Sector Outputs</th>
<th>ADB Sector Operations</th>
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</thead>
<tbody>
<tr>
<td>Outcomes with ADB Contributions</td>
<td>Indicators with Targets and Baselines</td>
<td>Output with ADB Contributions</td>
</tr>
<tr>
<td>Improved economic development in areas downstream of reservoirs</td>
<td>Reduction in poverty incidence in areas downstream of reservoirs</td>
<td>Replication of sustainable reservoir rehabilitation and management models established in Shandong Province, in other provinces in the PRC</td>
</tr>
<tr>
<td>Increase in investment and crop output value in areas downstream of reservoirs</td>
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**ADB = Asian Development Bank, PRC = People’s Republic of China.**