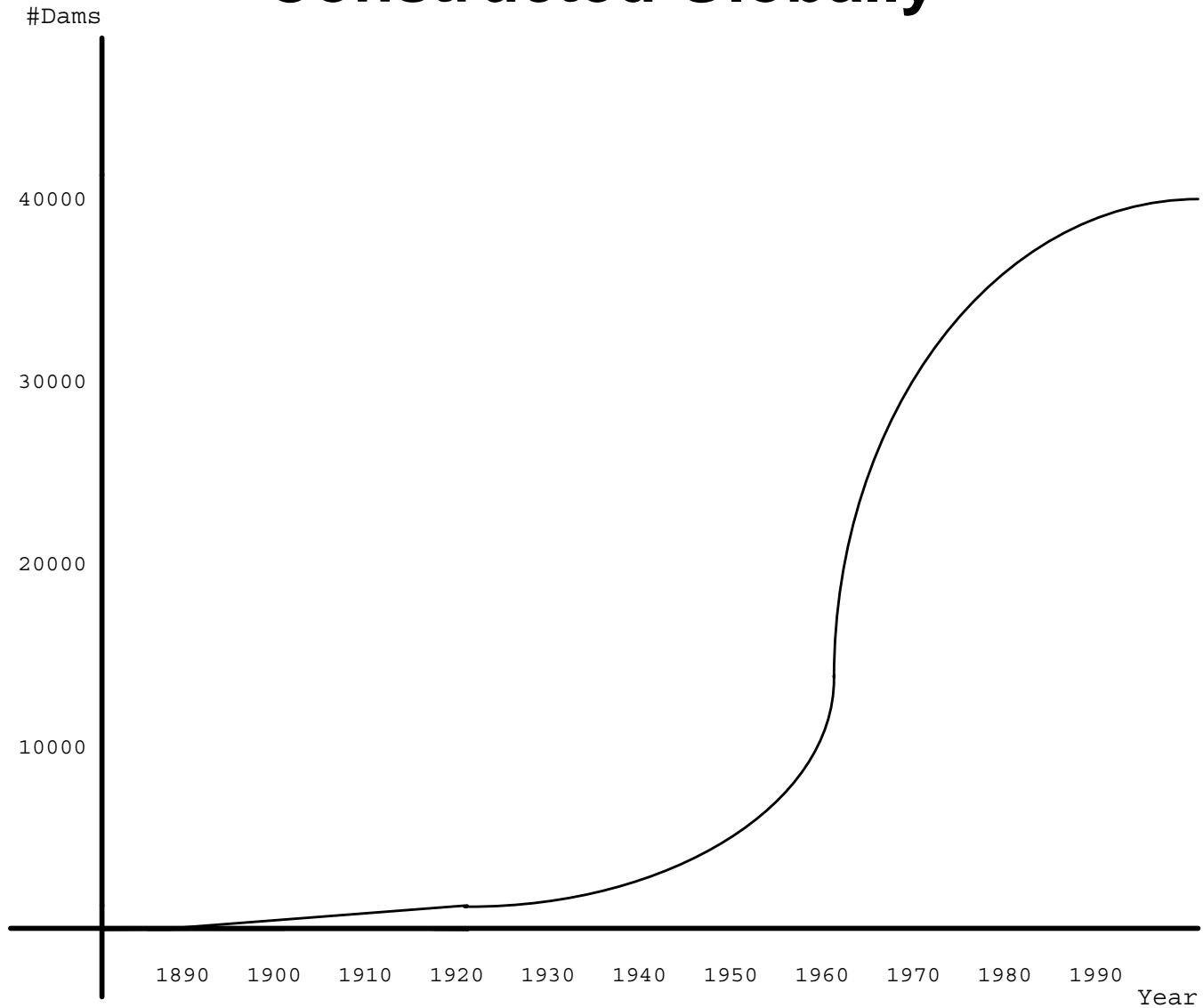


# **The Adaptive Management of Existing Dams For Sustainable Development**

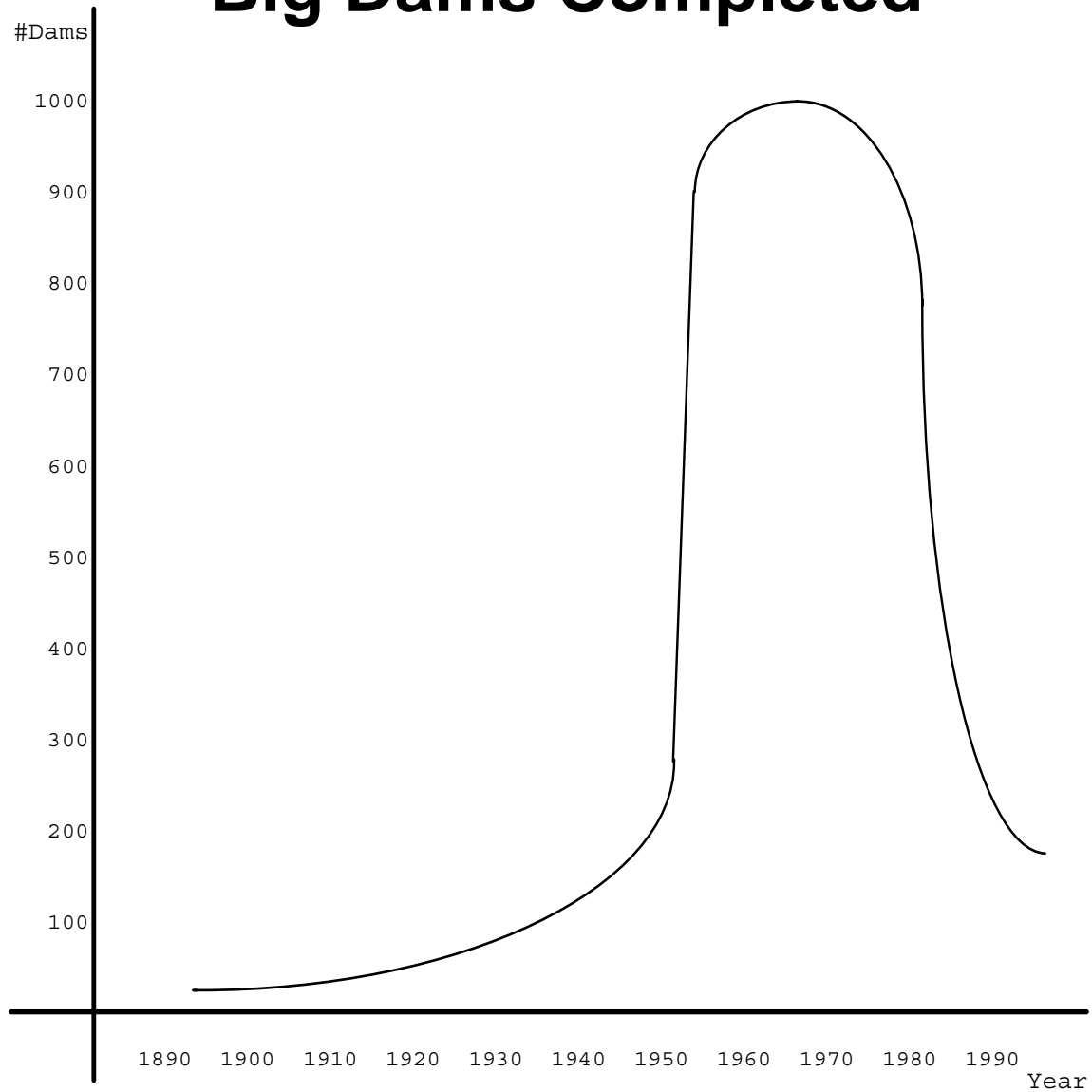
**Dr. Sanjeev Khagram  
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Evans School of Public Affairs  
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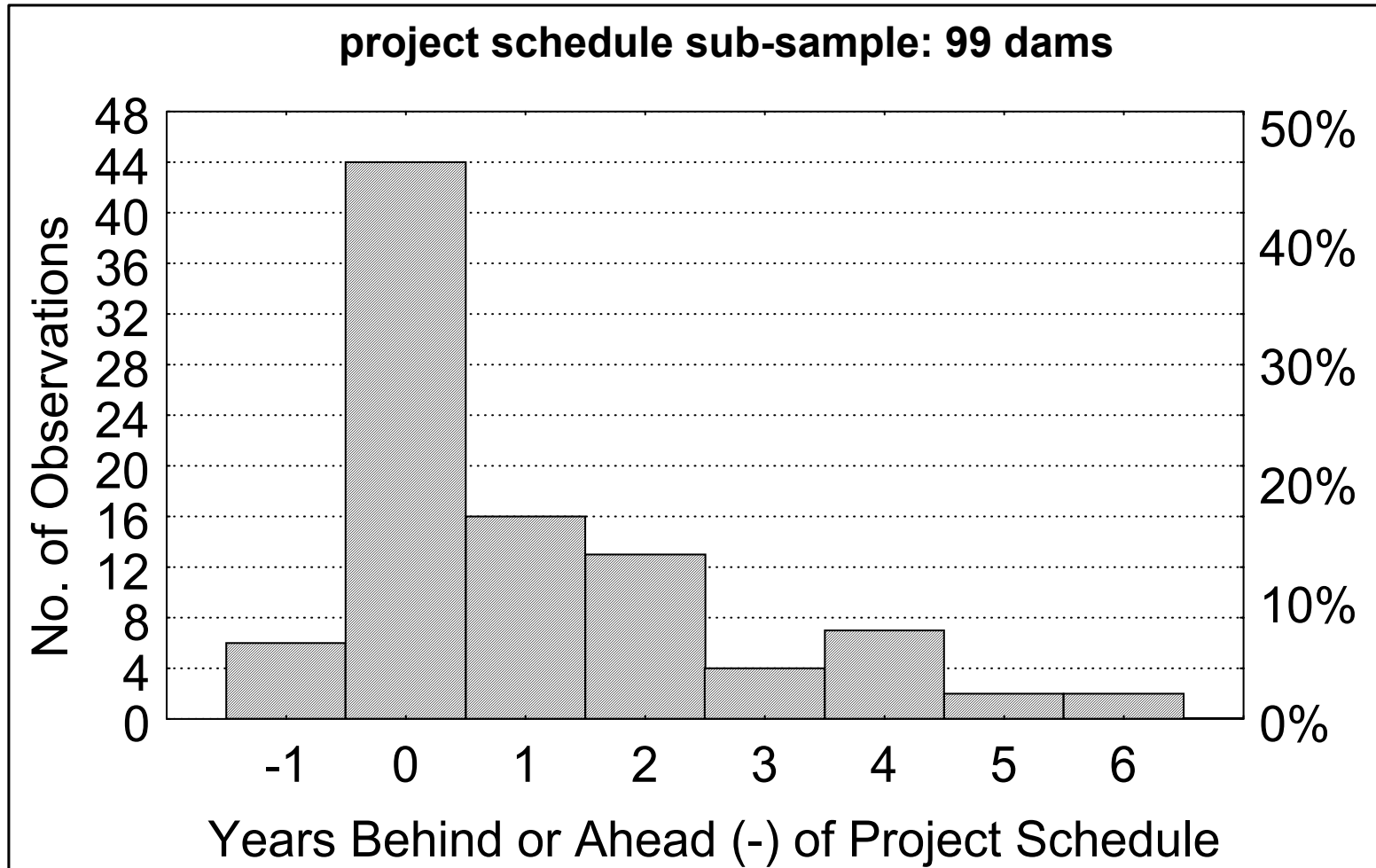
# Figure 1.1: Cumulative Number of Big Dams Constructed Globally



# Figure 1.2: Average Number of Big Dams Completed

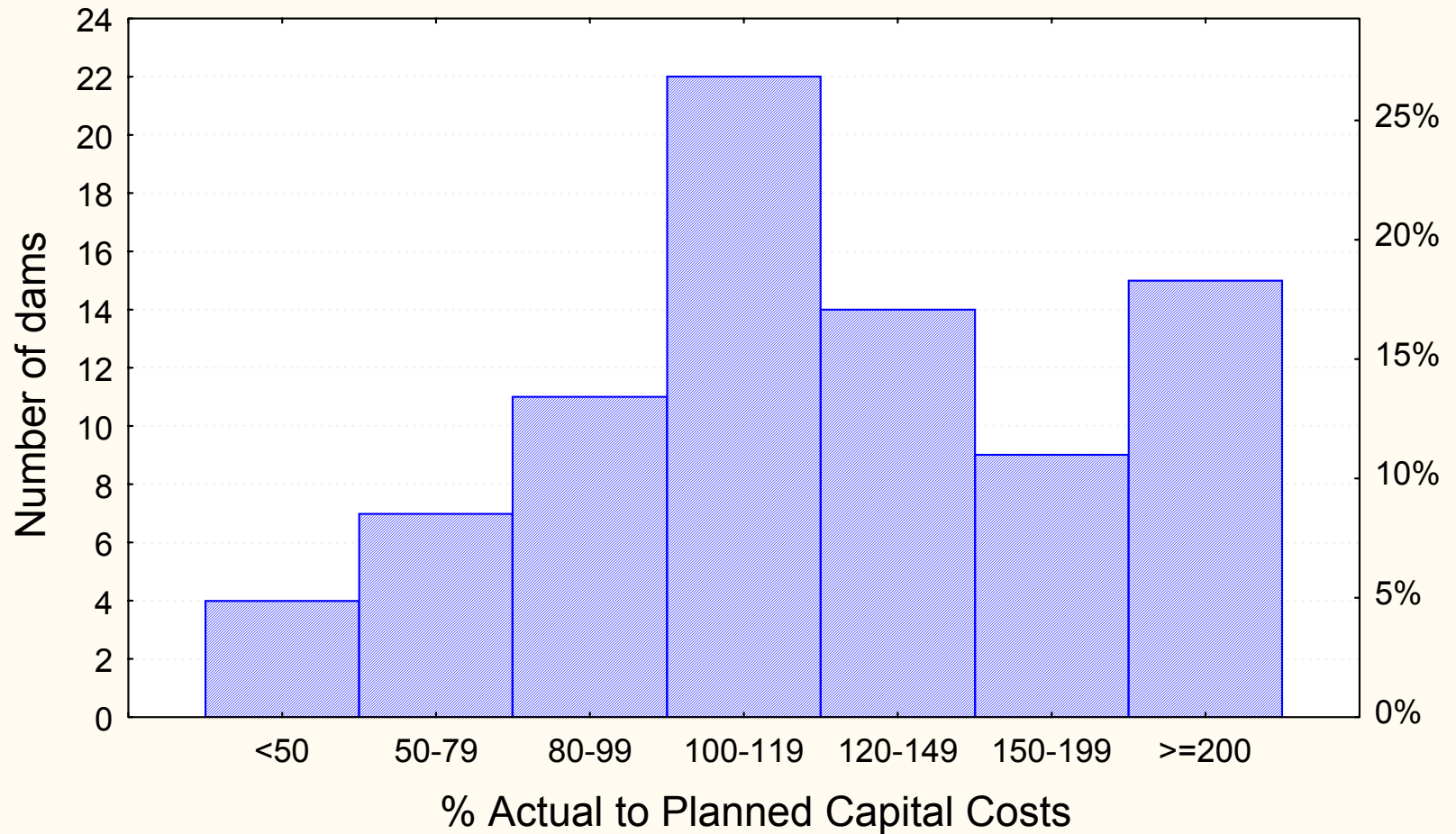


# Project Schedule Performance

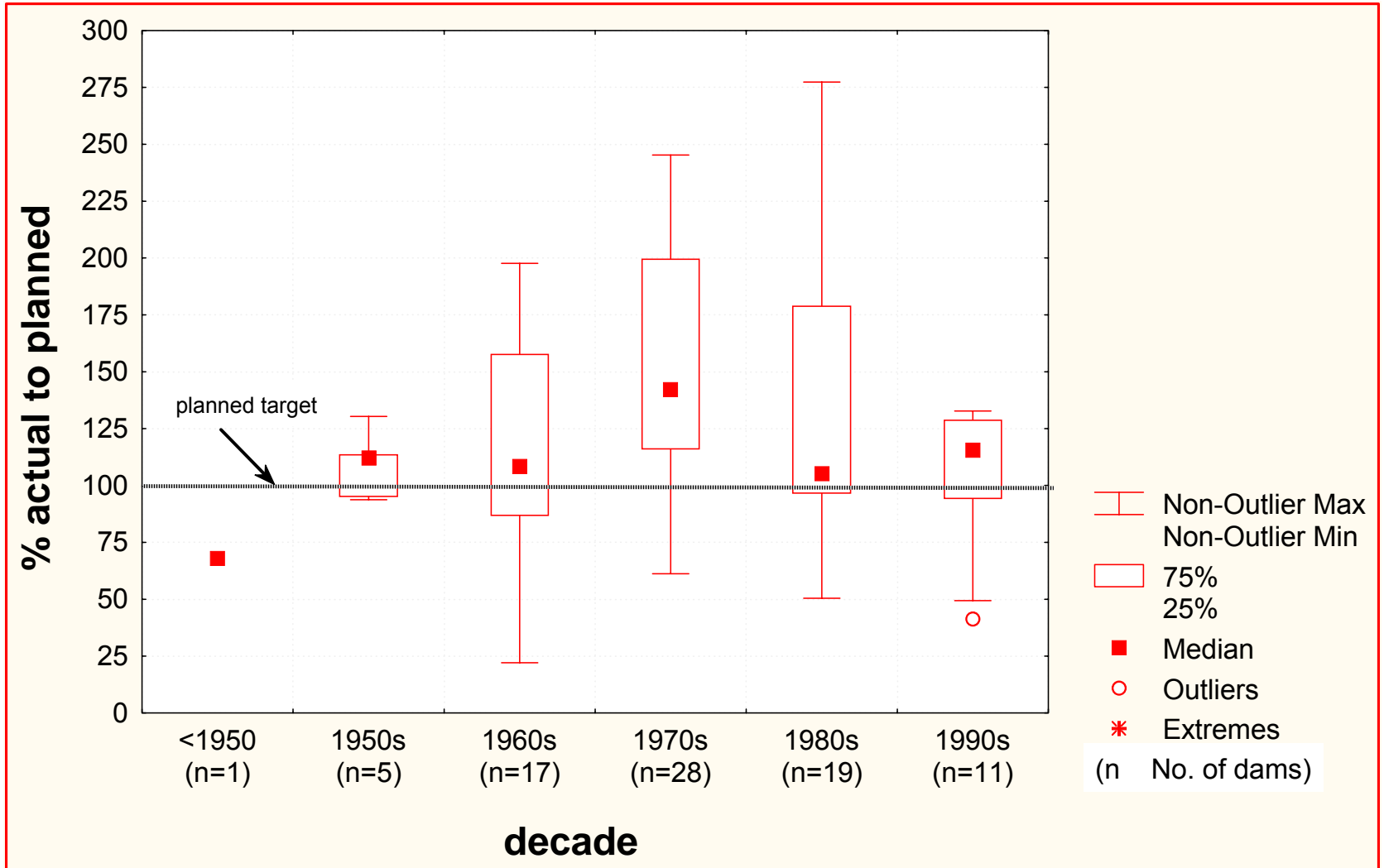


# Project Cost Performance

Global sub-sample: 81 dams (US\$ nominal)



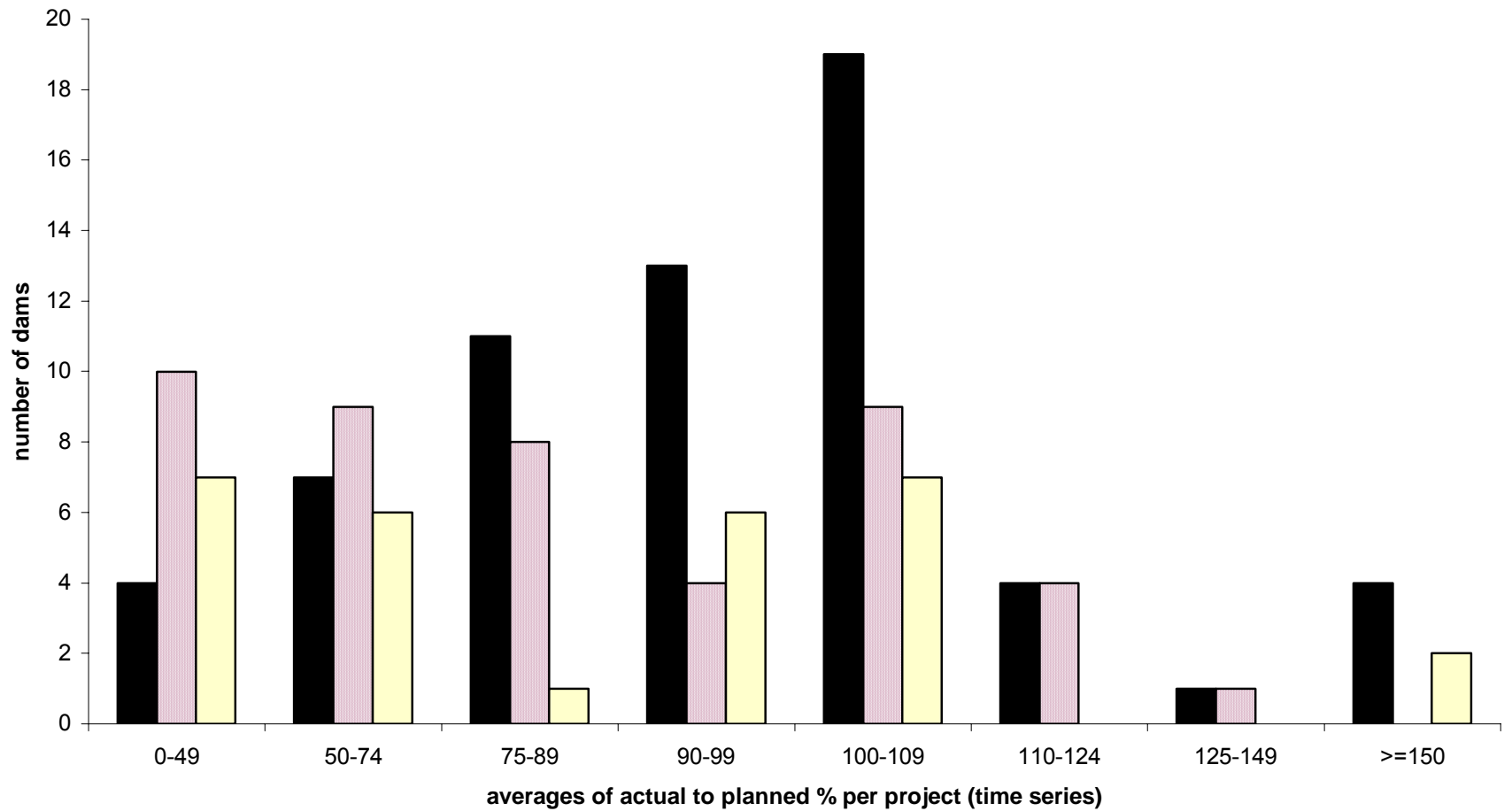
# Project Cost Performance



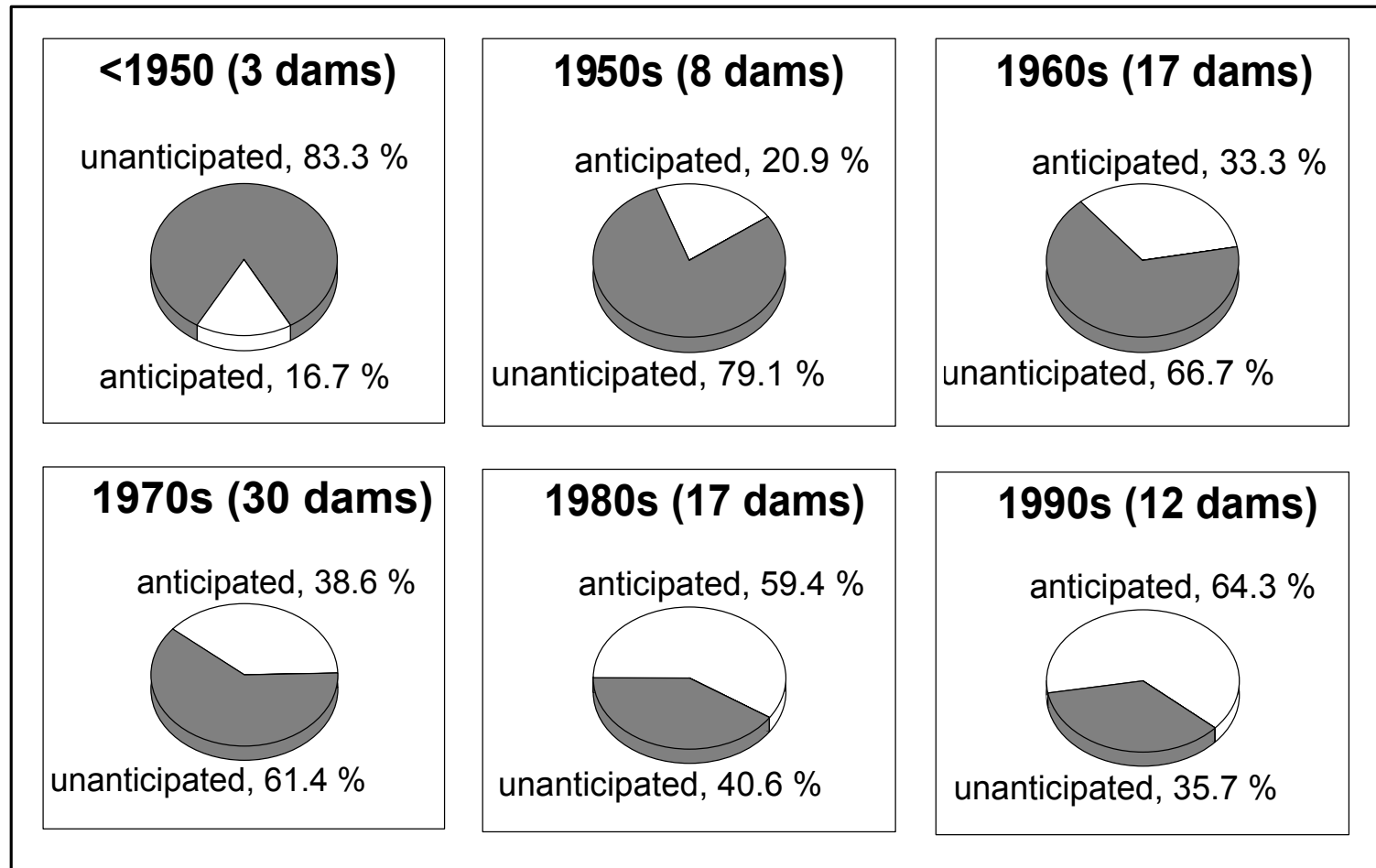
# Dam Service Delivery Performance

## histogram

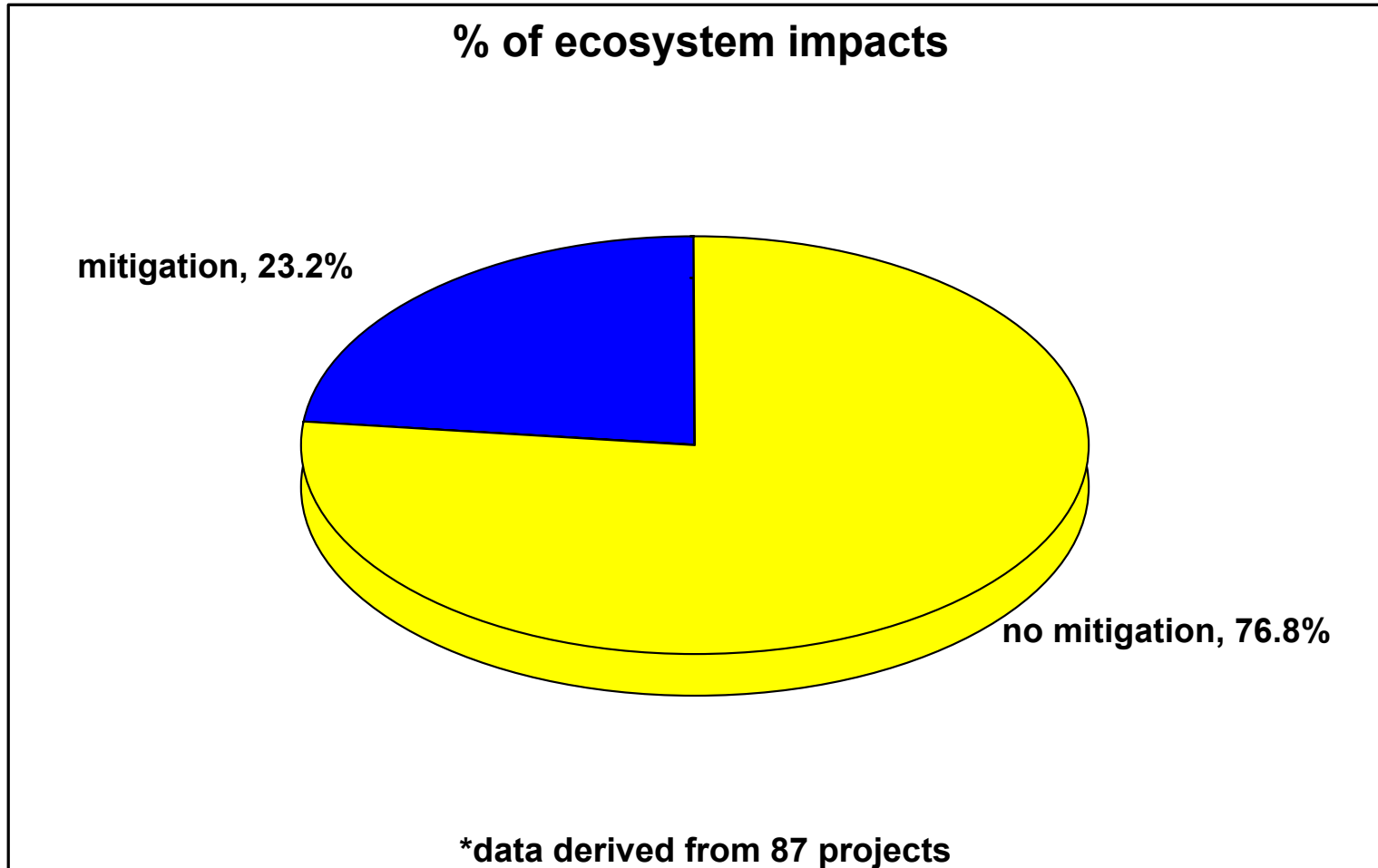
■ Hydro (63 dams) ■ Supply (29 dams) ■ Irrigation (45 dams)



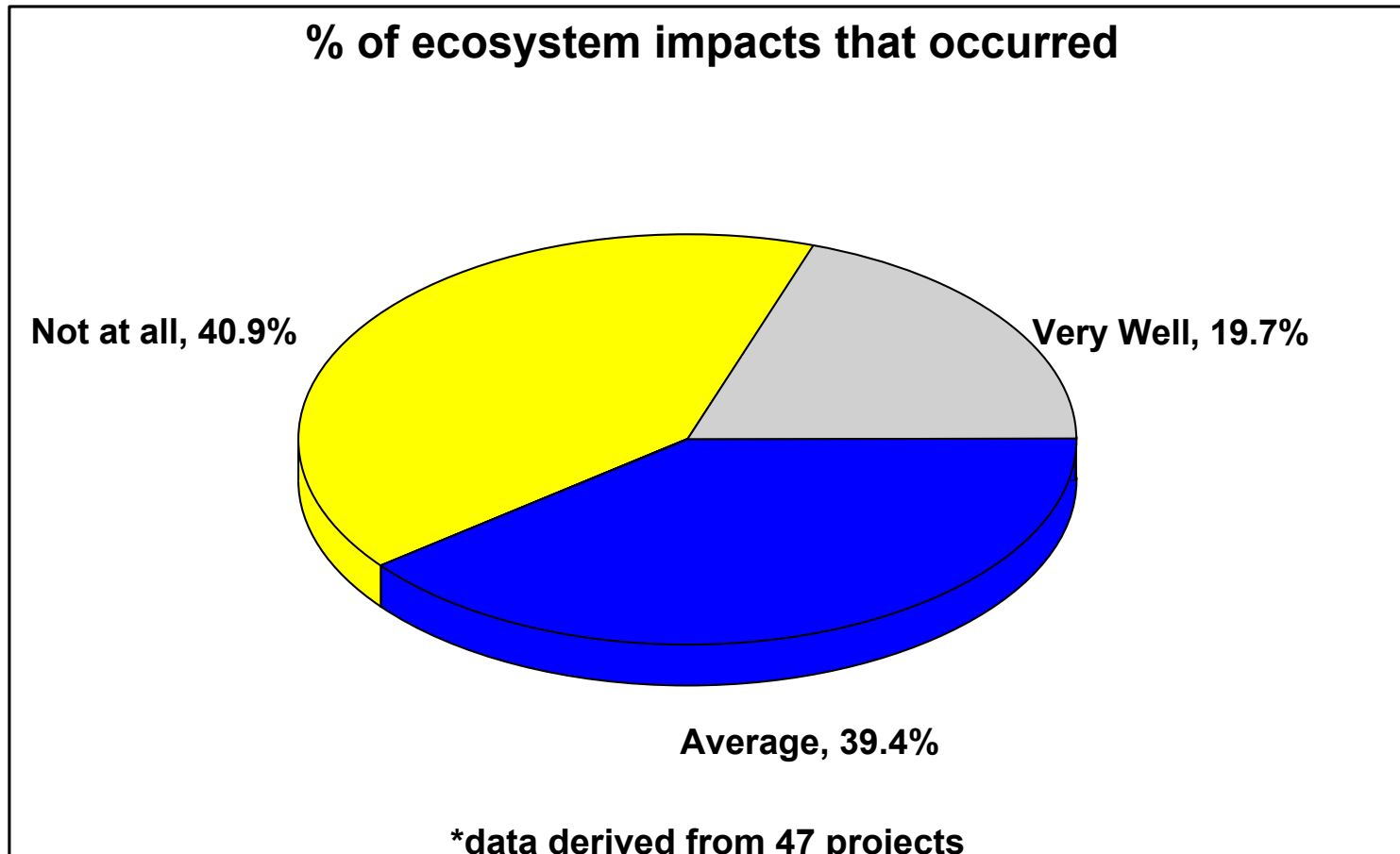
# Environmental Impacts and Mitigation: Anticipated and Unanticipated Ecosystem Impacts



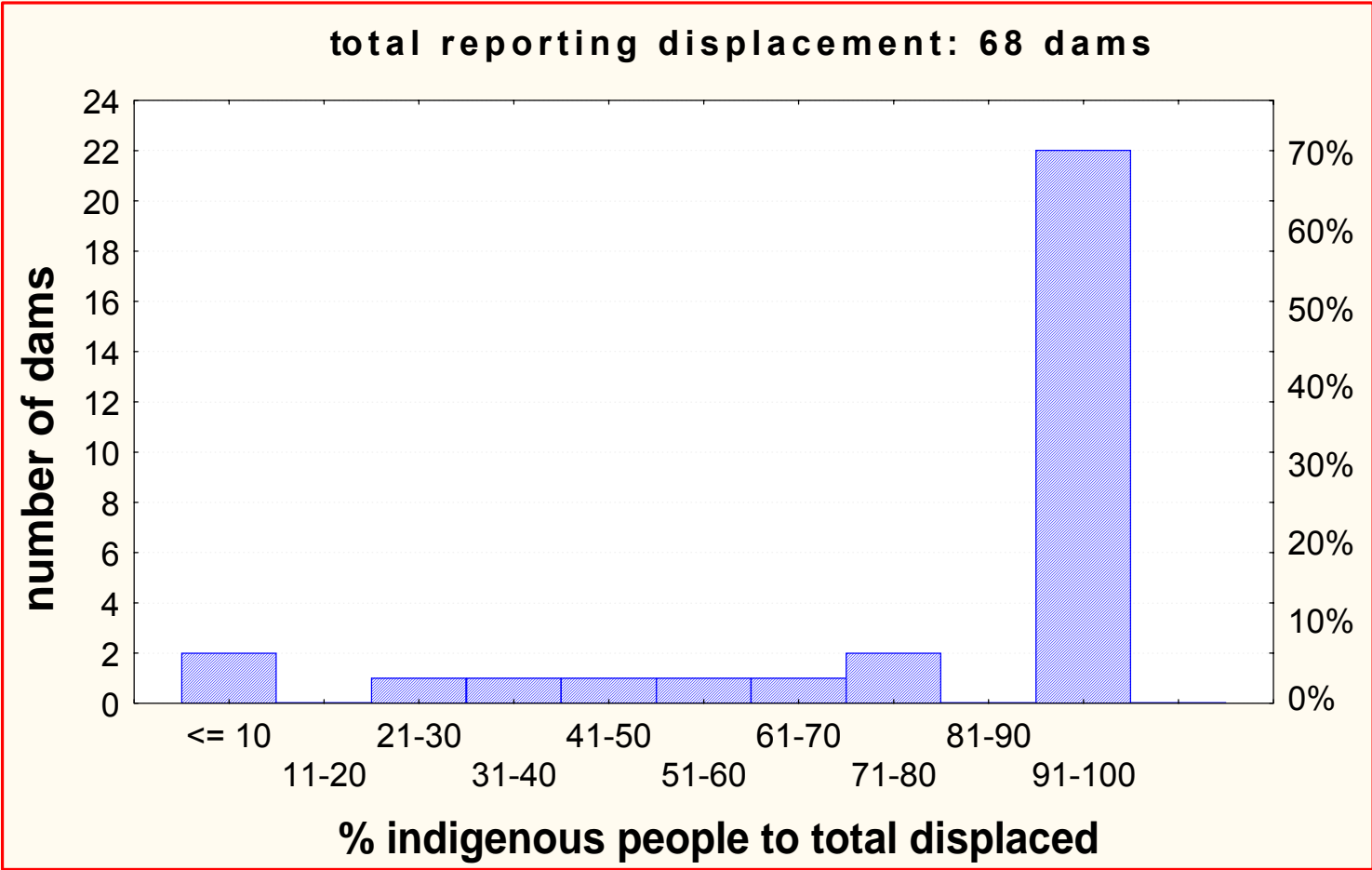
# Environmental Impacts and Mitigation: Planned Mitigation for Ecosystem Impacts



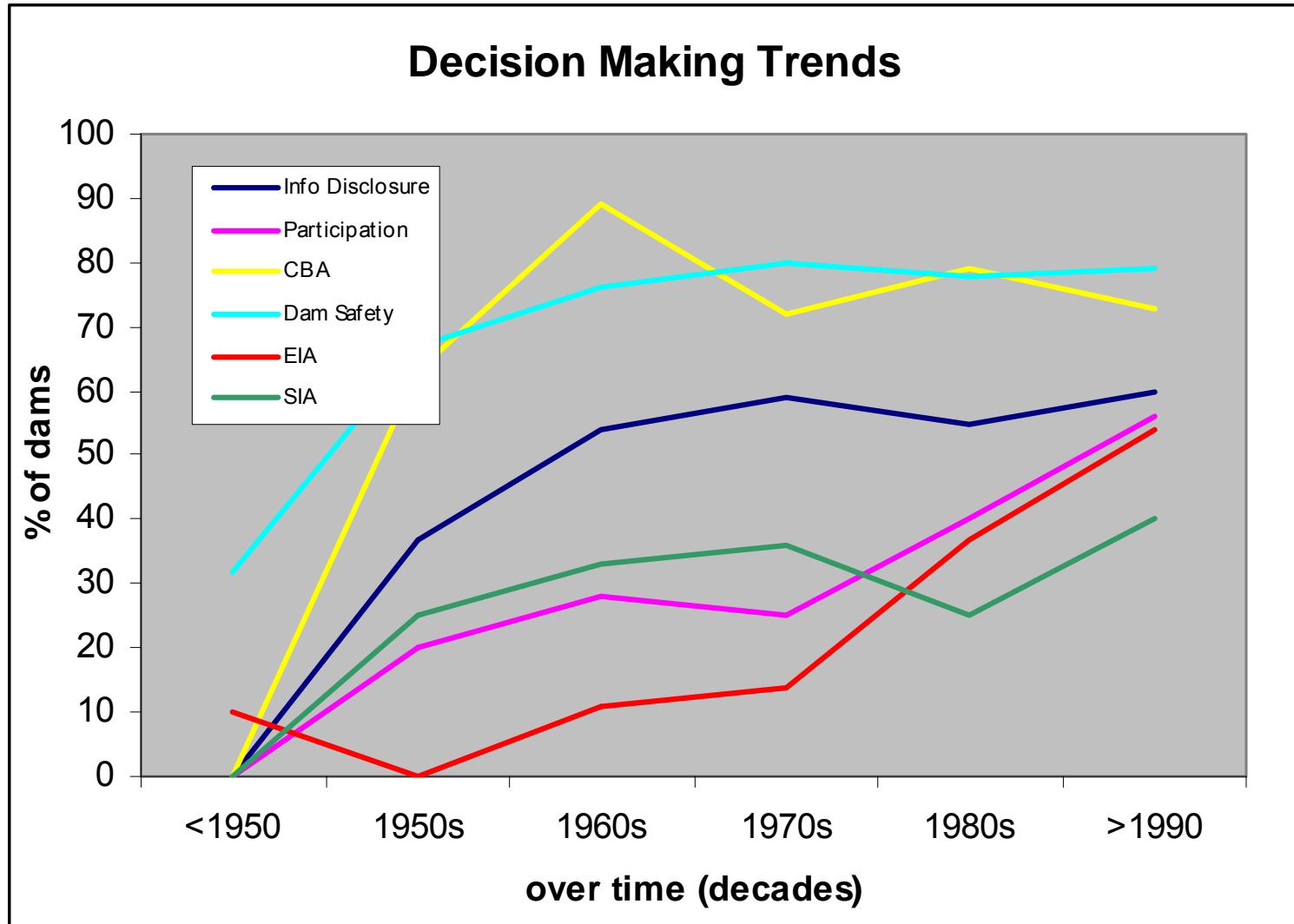
# Environmental Impacts and Mitigation: Effectiveness of Environmental Mitigation



# Social Impacts – Indigenous Peoples



# Decision Making and Governance



# Managing Existing Dams

## Monitoring and Evaluation for Adaptation

- A review of the world literature showed that monitoring of dam operations to determine their if actual benefits are not being realized and greater or unexpected costs have materialized.
- Monitoring provides data for adaptive management as well as information for measuring how effectively dams and the related facilities are being utilised.
- Many dams are operated without the comprehensive hydrometric data and analysis software that could be used to improve operations at a fraction of the cost of the monitoring. Monitoring to verify or to improve instream and reservoir environmental benefits and to minimise adverse impacts is even rarer such as environmental flow requirements.
- In 1997 Japan initiated an experimental program that requires dam performance reviews every 5 years. The reviews cover every aspect of benefits, costs, and safety associated with the operation of dams.
- Some countries like the United States have re-licensing requirements for state and privately-owned hydroelectric dams that provide opportunities for a comprehensive review and adaptive management.
- There is no consensus among countries on the elapsed time, which is up to 70 years, between such reviews. Hungary and Vietnam, for example, require inspections at periodic intervals, every ten years on average.

# Managing Existing Dams

## Optimizing Dam Operations

- Optimal operation of reservoirs requires managing the storage space in anticipation of future inflows and multiple needs for water. Optimization is a fundamental concept for increasing the efficiency and managing the tradeoffs in dam projects. It is a method that merits consideration at all dams throughout the world. In countries where capital is not readily available for building new dams it offers an affordable method for meeting an increment of needs. The concept of optimizing dam operations has become increasingly more important as operating criteria become more complex and requirements for environmental protection have become better understood.
- A prerequisite to optimal water management is a regulatory environment with key economic, social and environmental objectives clearly stated in a way that provides the dam operator maximum flexibility in determining how to achieve the objectives. In some cases the first step is to improve communications between those who have the data and its interpretation and those who need it. In other cases the very data required to operate effectively may not be available in time to influence decisions.

# Operations Optimization: The Nam Ngum Case

- Nam Ngum is a 150 MW hydropower plant near Vientiane, the capital of Lao PDR. Not all power can be consumed in the country and the surplus power is exported to Thailand. The power sales agreement between the two countries foresees that the export tariff is revised every 4 years. The objective of the study, which was financed by the Asian Development Bank, was to find means by which the operation of the project could be changed to maximize the income for the Lao Government, hydro-electricity being one of the most important foreign exchange income earners.
- The study started with a detailed simulation of historical operation to derive the net inflow series into the Nam Ngum reservoir from 1971 when the project was commissioned, to 1990 the year the study was done. Employing regression techniques with rainfall data, the inflow was extended, including the years 1949-1989. The study proposed a time-of-day tariff with three time slots: peak, partial peak and off peak hours, with the highest tariff for peak hours and the lowest tariff for off peak hours.
- Application of a monthly stochastic dynamic programming model then derived switching curves, depending on the month and the water level in the reservoir. These curves determine whether the project should, in addition to covering the local demand in Lao PDR, maximize output for exports during 24 hours per day, during the peak and partial peak hours, only during peak hours, or not at all.
- This new mode of operation was successfully negotiated with the Thai authorities. Appropriate software was installed on the project computers to update the data sets for changes in the local demand and new hydrological variation, and to let the operators from day to day know during which hours which turbines had to be run with what capacity. Net benefits are estimated to be approximately US\$ 2 million per year. Assuming the same average tariff, the revenues from power sales to Thailand increased by about 10%.

# Operations Optimization in British Columbia

- Since 1987 a computerized decision support system (DSS) has been used to guide weekly reservoir release decisions at two hydroelectric plants in the coastal mountains of British Columbia, Canada ([www.chal.bc.ca](http://www.chal.bc.ca)).
- Studies of 1970-1974 operations (a period before the decision support system became operational) showed that, compared to operation with perfect foresight as derived with a deterministic optimisation model, the rule curve based operation had produced 83.4-percent of the maximum attainable energy compared to 95.1-percent with the full DSS.
- Without the hydrologic forecast component the optimisation component would have produced 92.8-percent by simply using long-term average monthly inflows in place of the forecast. The actual energy produced by operating with the DSS in each year between 1989 and 1993, compared to the maximum possible, was 100, 93, 98, 94 and 96 percent.
- The DSS provides accessible data and a consistent framework for improving operating decisions.

# Managing Existing Dams

## Water Quality and Human Health

- Reservoirs affect water quality within the reservoir itself and in the downstream river. Temperature stratification within the reservoirs leads to areas of low oxygen (less than 5 ppm) in which animals cannot flourish and to anaerobic conditions conducive to undesirable chemical reactions in reservoir sediments.
- The conventional solution to problems stemming from temperature stratification is to use a network of submerged pipes to aerate the reservoir areas that are subject to low oxygen concentrations. Another method takes advantage of the small difference in density in stratified reservoirs and uses mechanical mixing to provide the uniform temperature distribution that supports higher concentrations of oxygen. Releases from upstream reservoirs can be scheduled to provide cooler aerated water to downstream reservoirs at critical times of year.
- Mercury in flooded soils may be released into more mobile forms that bioaccumulate into toxic concentrations at higher trophic levels. There are no known operational fixes for this problem – fish caught in reservoirs must be monitored to detect high concentrations before they become human health problems.

# Managing Existing Dams

## Flood Adaptation

- The potential for floods varies seasonally with the climate and with day to day changes in a soil moisture and snow cover. Thus the flood frequency curve and the probable maximum flood are conditional on the time of year and the current state of the watershed. The portion of the total reservoir storage reserved for flood control therefore varies with these factors.
- Since the 1960's in the Columbia River of the USA and Canada, the current hydrological condition of the basin has been used each year to revise the allocation of storage for flood control. The goal of this procedure is to maximise the utilisation of reservoirs for non-flood control purposes without sacrificing flood protection for downstream areas or dam safety.
- Monitoring and modelling is incorporated effectively into the reservoir operations procedures. Land around reservoirs is normally acquired and dedicated to uses that are not damaged by high water levels.
- If this is not the case, reservoir operations to control floods must consider the tradeoff between damage from downstream flooding caused by large releases, and upstream flooding as reservoir levels rise far above normal.

# Managing Existing Dams

## Ageing, maintenance, rehabilitation and upgrading

- Dams and their appurtenant structures inevitably are ageing. The International Commission on Large Dams (ICOLD) reported on over 1000 case histories of deterioration of dams.
- The report discussed the mechanism of the ageing process, how this is detected and the effect of the deterioration on the operation and safety of the dam.
- Recommendations were made for all types of dams to reduce the rate at which ageing occurs, and to reduce the impact of that which has occurred.
- Aging is a critical issue that requires ongoing attention to hundreds of details that ensure the longevity, productivity and safety of dams.

# Managing Existing Dams

## Dam Safety in China

- The Ministry of Water Resources has broad responsibility for the safety of dams and flood levees throughout the country. There are two National Dam Safety Centers. The centre for concrete dams is located in Hongzhou: the one for earth and rockfill dams is in Nanjing.
- The Ministry of Water Resources has issued numerous dam-safety guidelines and regulations: Safety Management of Reservoir Dams; Flood Control Criteria; Evaluation Procedures for Reservoir Dams, and the 1991 Regulation of Dam Safety Management. The Law of Flood Control for China (January 1998), requires that emergency-preparedness plans be established for each dam above a certain size.
- Chinese sources describe some notable dam failures in China. In August 1975, a typhoon created a maximum 24-hour rainfall of 1 005mm and a three-day rainfall of 1 605mm in Henan Province. This unprecedented event caused the failure of the Banqiao Reservoir on the upper reach of the Ruhe River. The flood caused by the typhoon combined with the dam failure inundated more than one million ha of land, over 100 km of the Beijing-Guangzhou railway line was damaged, and more than 20 000 lives were lost. In 1993, the Gouhou Dam in Qinghai Province failed when the concrete slab on the rockfill failed and 1 200 people died.
- A recent Dam Safety Management and Monitoring Project (1999) recommended the establishment of a Dam Safety Regulatory Agency to assume responsibility for dam safety management. Its proposed tasks include advice and assistance to the Ministry of Water Resources in drafting regulations, taking responsibility for enforcement for dam safety and overseeing the production of guidelines and standards for inspection and safety appraisals.
- Recommendations include the need for new regulations and guidelines to cover the areas of owners' responsibilities, frequency of inspections, record-keeping requirements, qualification of personnel, etc.

# Managing Existing Dams

## Decommissioning

- Many dams have been decommissioned but most have been small, less than 15 meters in height, and the environmental improvements have been tangible. As far as known, there has never been a dam exceeding 40 meters in height decommissioned.
- Decommissioning is a viable option if the costs of further operation outweigh its ongoing benefits - that is, the dam has gone beyond its useful life.
- Decommissioning, however, refers to a range of possible actions, from ceasing operations of a dam, breaching it to allow fish passage and navigation, and to the full dismantling and removal of structures (like the Elwha)
- Dams are potentially finite, and thus decommissioning is likely to become more of an issue throughout the world in the future. But the costs and mechanics of dam decommissioning or removal are major and have not usually been considered as part of the life cycle costs, nor included in overall benefit-cost ratios when deciding on the feasibility of new dam projects.
- It seems reasonable that future dam projects will be required to include a fund for decommissioning and a mandatory decommissioning methodology. What should be done about financing decommissioning of existing projects remains unclear.

### Dams Removed in France

Dam	Height (m)	Year Built	Year End	Cost (Mil US\$)
Kernansquillec Leguer	15	1920	1996	1.0
Saint-Etienne	12	1895	1998	1.1
Maisons-Rouges	4	1922	1998	2.3

# Managing Existing Dams: Policy and Practice Implications

- Focus on improving operations and adaptive management of existing assets
- Create conditions for transparent, participatory, multi-criteria, options assessment for sustainable water resources development
- New mechanisms to ensure compliance with and implementation of social and environmental policies and safeguards