11.479J / 1.851J Water and Sanitation Infrastructure in Developing Countries
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Comparison of Beijing Municipality and MWRA (Boston) Water Systems

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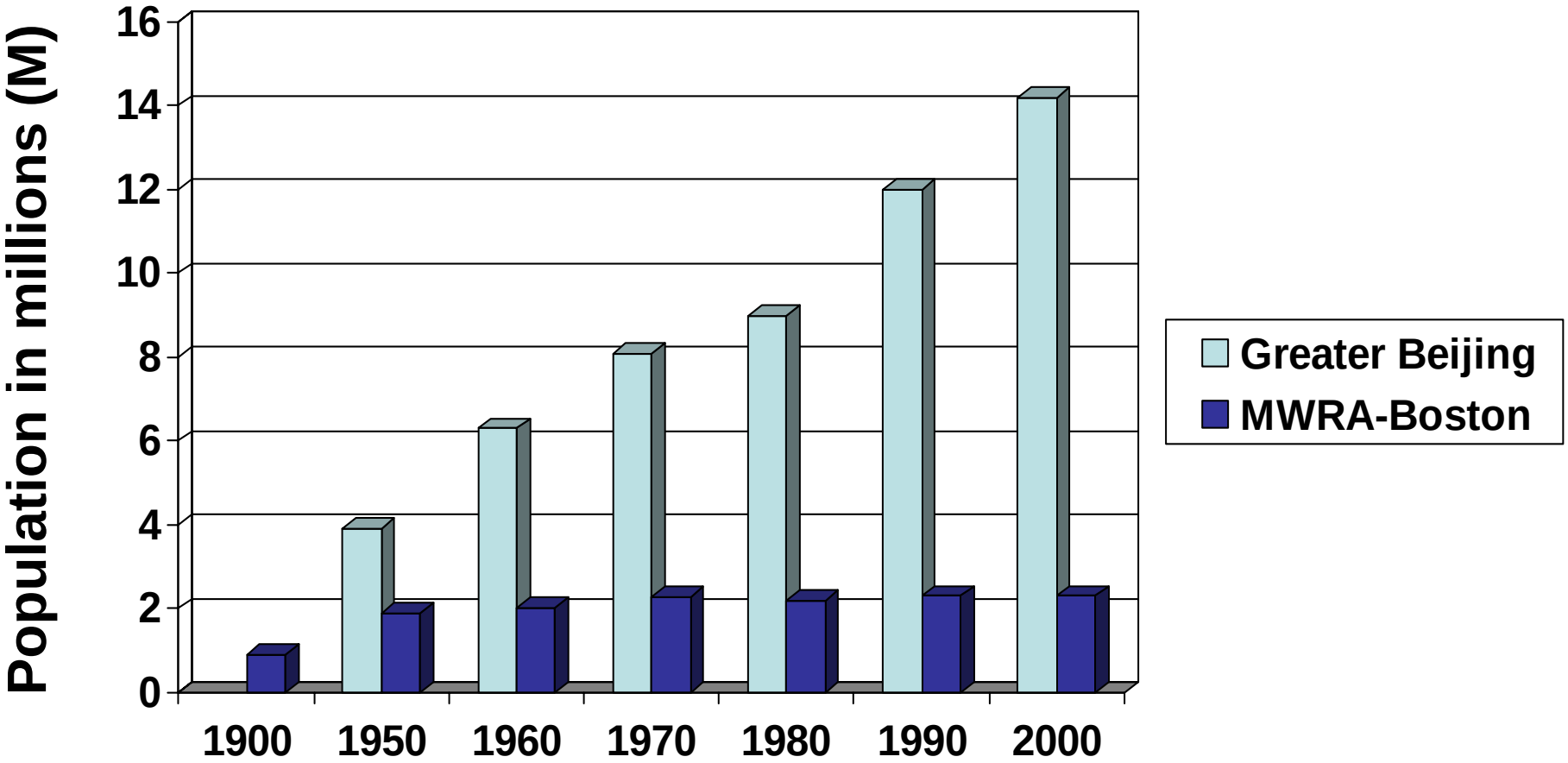
Beijing, China

- Beijing is China’s political and cultural capital
- A 3000 year old city; over 700 years as capital
- Beijing is not located on a major river

Beijing - Demographics

- City Population – 10 million
- Beijing Municipality – 14.2 million

Comparison – Population of Greater Beijing & Boston (MWRA)



Beijing Population #s from:
www.aag.org/HDGC/www/urban/supporting/supmat11a.pdf

Boston #s from MWRA (Das,J. 2007)

Relations between distribution of cities and average rainfall

Map removed due to copyright restrictions.

Average annual rainfall in Beijing = 400 – 600 mm/year (580 mm/yr)

Average annual rainfall in Massachusetts = 1400 mm/year

Beijing and North China Plain – Available Water

- Beijing located in the arid North China Plain
- Available water per capita (AWPC) is the lowest in SE Asia (Shalizi, World Bank, 2006).
- China's AWPC is 25% of world's average; (Liu, 2006)
- North China Plain's AWPC is 15% of China's average and 3.75% of world's average. (Liu, 2006)

• AWPC is 350 m3 per capita (Berkoff, 2003).
• The international average is 1,000 m3 per capita.

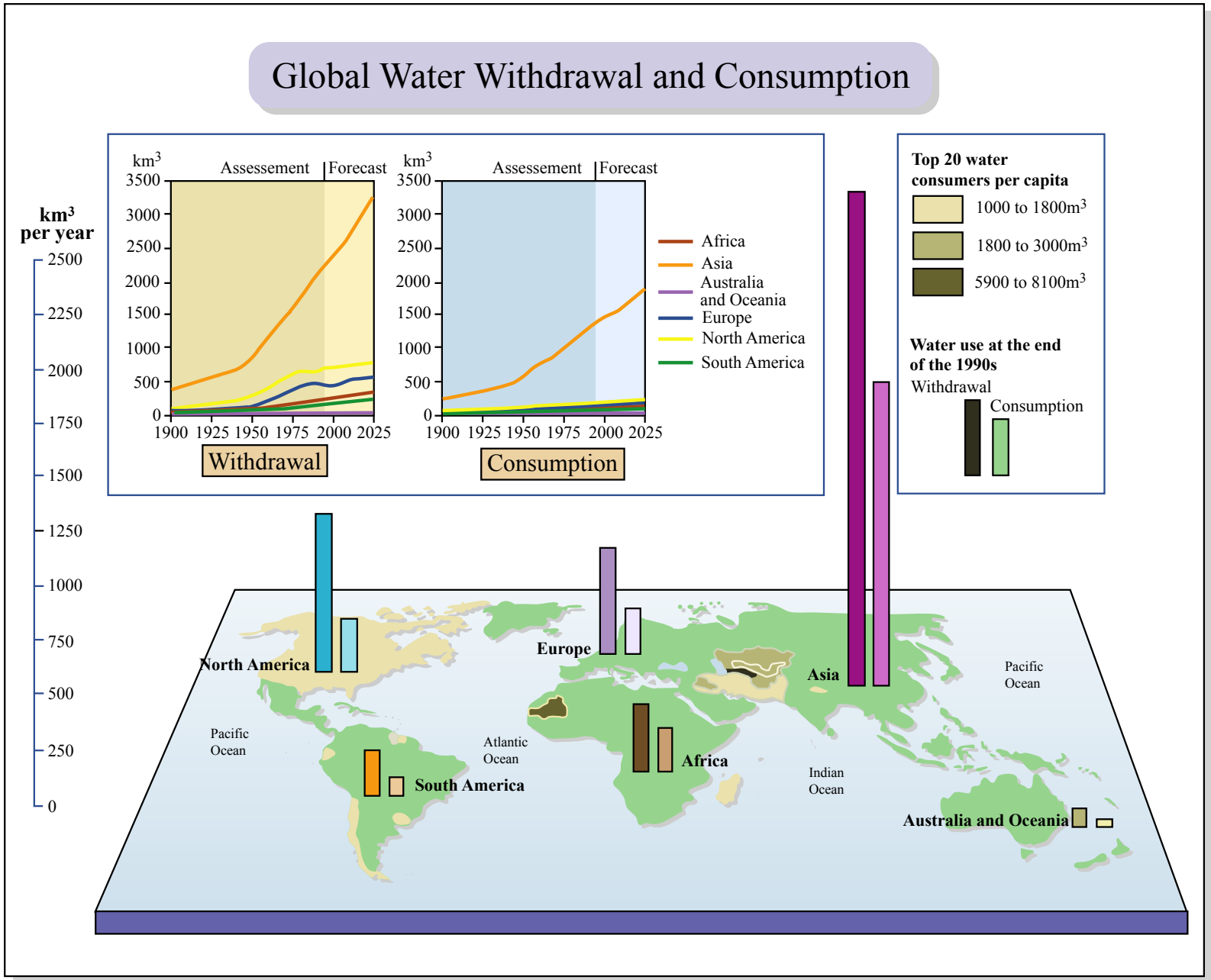


Figure by MIT OpenCourseWare.

China's Water Resources and the North China Plain

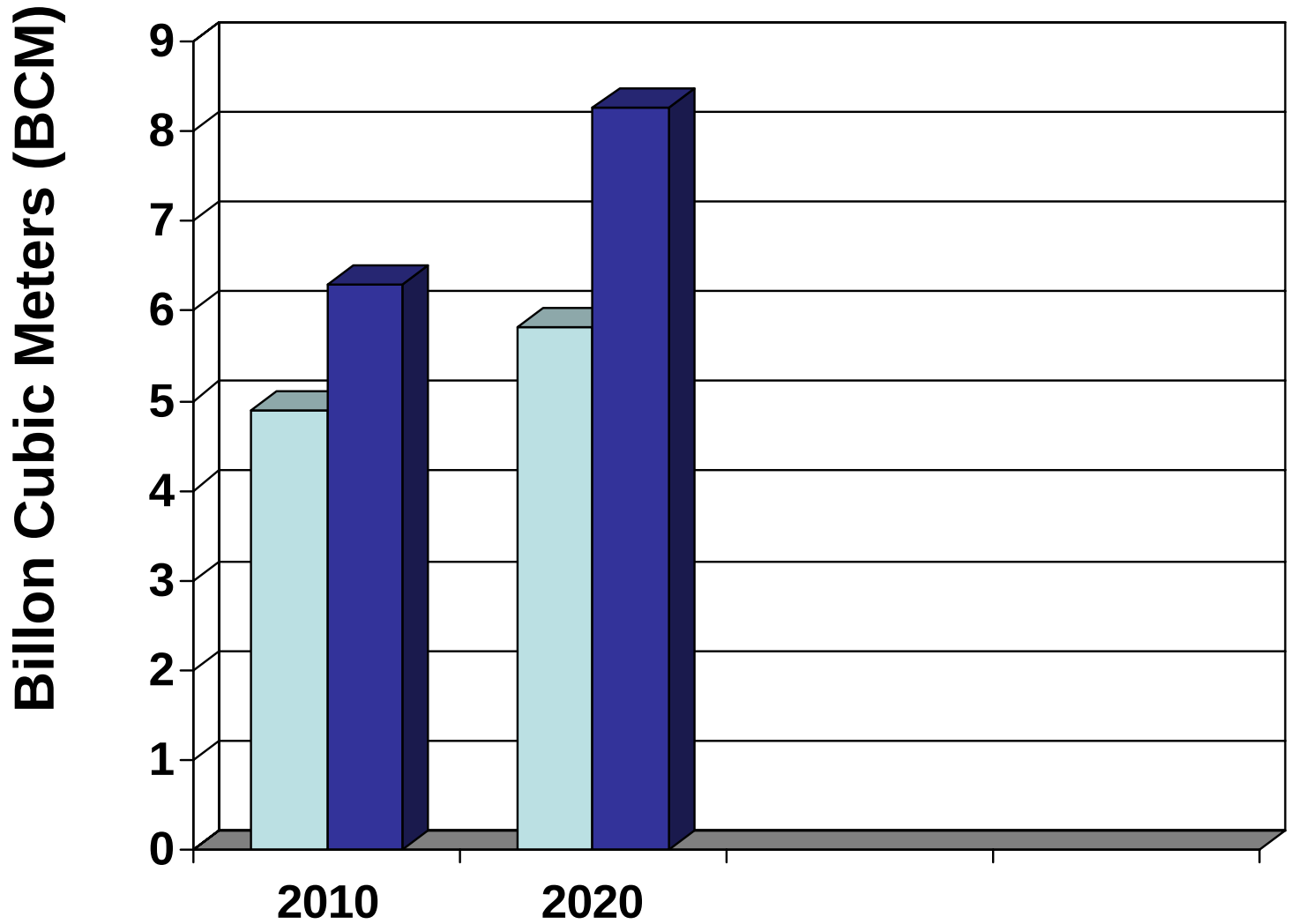
- North China Plain has 25% of China's population and it is served by 3 major rivers: the Hai, Yellow (Huang) and Huai.
- 80% of China's water resources are in the Yangtze and south of the Yangtze, but only 50% of population live in the South. (Ministry of Water Resources, 2000)
- North China Plain: groundwater levels have dropped as much as 4 m/year. (Gleick, P. 2000)
- An estimated 3.6 M wells are used mostly for irrigation in North China.
- North China Plain produces > ½ China's wheat and 1/3 China's corn. (Brown, L. 2003).

Beijing Municipality – Water Use

- 64% groundwater, 36% surface water
- Total Water Use = 4.05 BCM (1995) (Beijing Municipal Government,1999)
- "Available Water" = average quantity of water available on a renewable basis
- **Available Water = 2.6 BCM groundwater + 1.5 BCM surface water**
  = 4.1 BCM total (annual)(2000) (Wang et al, 2006)
- **Since 2000, efficiency is increasing and "is almost the best in China." Available water in 2005 is now only 3.4 BCM (Ministry of Water, 2007)**
- Average water demand projections
  - 2010 = 4.90 to 6.29 BCM
  - 2020 = 5.82 to 8.25 BCM (Wang et al, 2006)

Low and High Demand Projections

Beijing Municipality (2010 & 2020)



(Wang et al, 2006)

Beijing Water - Forecasting

- Beijing Gov't estimates shortfalls of 1+BCM (2010) to 2+BCM (2020) (Wang, 2006)
  - Could it actually be worse?
  - What about a dry year or extended drought? (Compare to 300-year drought in MWRA-Boston system in the late 1960s)
  - Climate change impacts?
- When will growth of Beijing population slow down?

As in Boston in the 17th and 18th centuries, so too Beijing city water was traditionally drawn from wells and springs

Beijing Water Supply History

- Water shortages in Beijing have been an issue for centuries
- As far back as 1153, there were concerns over Beijing's water supply

(Hou, E. and Hunter, undated)

Beijing Water Supply History

- In early 20th century, tap water was a new invention that arrived at the same time as foreign armaments. It was not surprising that Chinese would resist it.
- Potable water plants were strongly objected to by the people when they were first introduced in foreign concessions and even riots broke out in some cities.
- The Beijing Water Plant faced problems going through the Imperial City Wall, moat, Gold Water River (People paid attention to *fengshui* especially in the Forbidden City)
- People considered water passing through pipes as “foreign water.”
- Some called water treatment plant water “machine water.”
- In Tianjin, there were rumors that “machine water” would affect a woman’s fertility.
- From 1908 to 1949, the water industry in Beijing experienced many different influences, the late Qing Dynasty, a period of Japanese control, the period of Kuomintang rule. As a consequence, the water industry developed slowly. There was only one potable water plant in Beijing until 1949.

(Yilin, Gu, 2006)

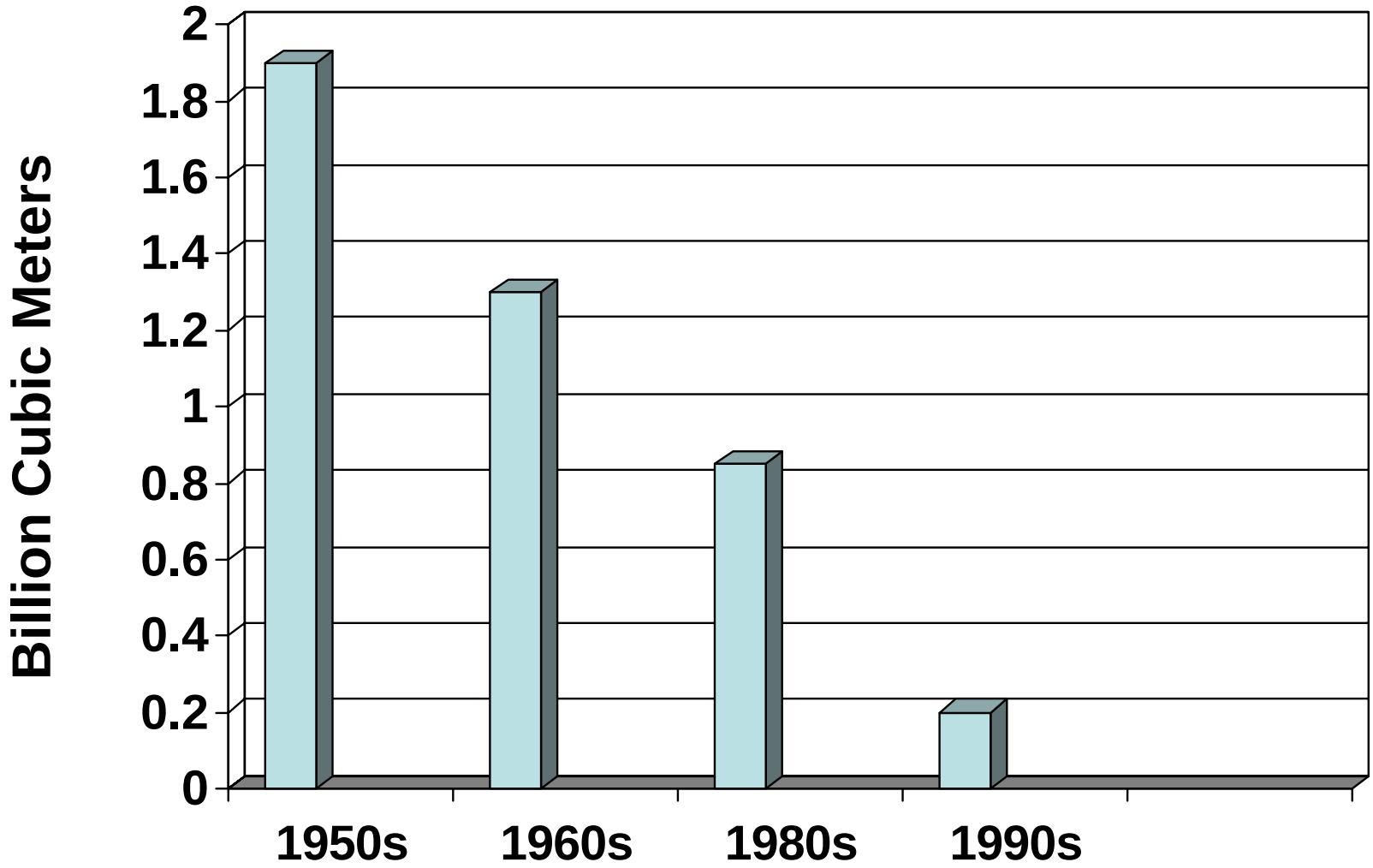
Beijing Water Supply History

- First large scale projects – 1950s
- 85 water reservoirs were built with an estimated 7 billion cubic meters (BCM) of storage capacity
- Extensive groundwater use
- Yet, increasing demand -> water shortages

(Hou, E. and Hunter, undated)

Declining Inflow to Quanting Reservoir

(Design Capacity = 2.2 BCM)



Quanting Reservoir

- China’s first large reservoir
- Completed in 1954
- Total Capacity = 2.2 billion cubic meters (BCM)
- 1950s inflow = 1.9 BCM
- 1960s inflow = 1.3 BCM
- 1980s inflow = 0.85 BCM
- 1990s inflow = 0.2 BCM
- 1997 – Quanting no longer supplying drinking water because of pollution

Comparison of Reservoir Capacity MWRA (Boston) and Beijing

	Storage	Depth (feet)	Length (mi)	Width (mi)
Quabbin	1.6 B m3 (BCM) (412 B gallons)	150	18	3
Wachusett	246 million m3 (65 B gallons)	129	8.5	1
Quanting	2.2 B m3 (BCM)	1544 (?)		
Miyun	0.8 -1 B m3 (BCM)	446 (?)		
Huai Rou	0.2 BCM	184 (?)		

Boston's Quabbin Reservoir capacity is larger than Miyun, but smaller than Quanting.

(Reference: Chinese data translated by Fenghua Liu, 2007)

QuanTing Reservoir is severely depleted

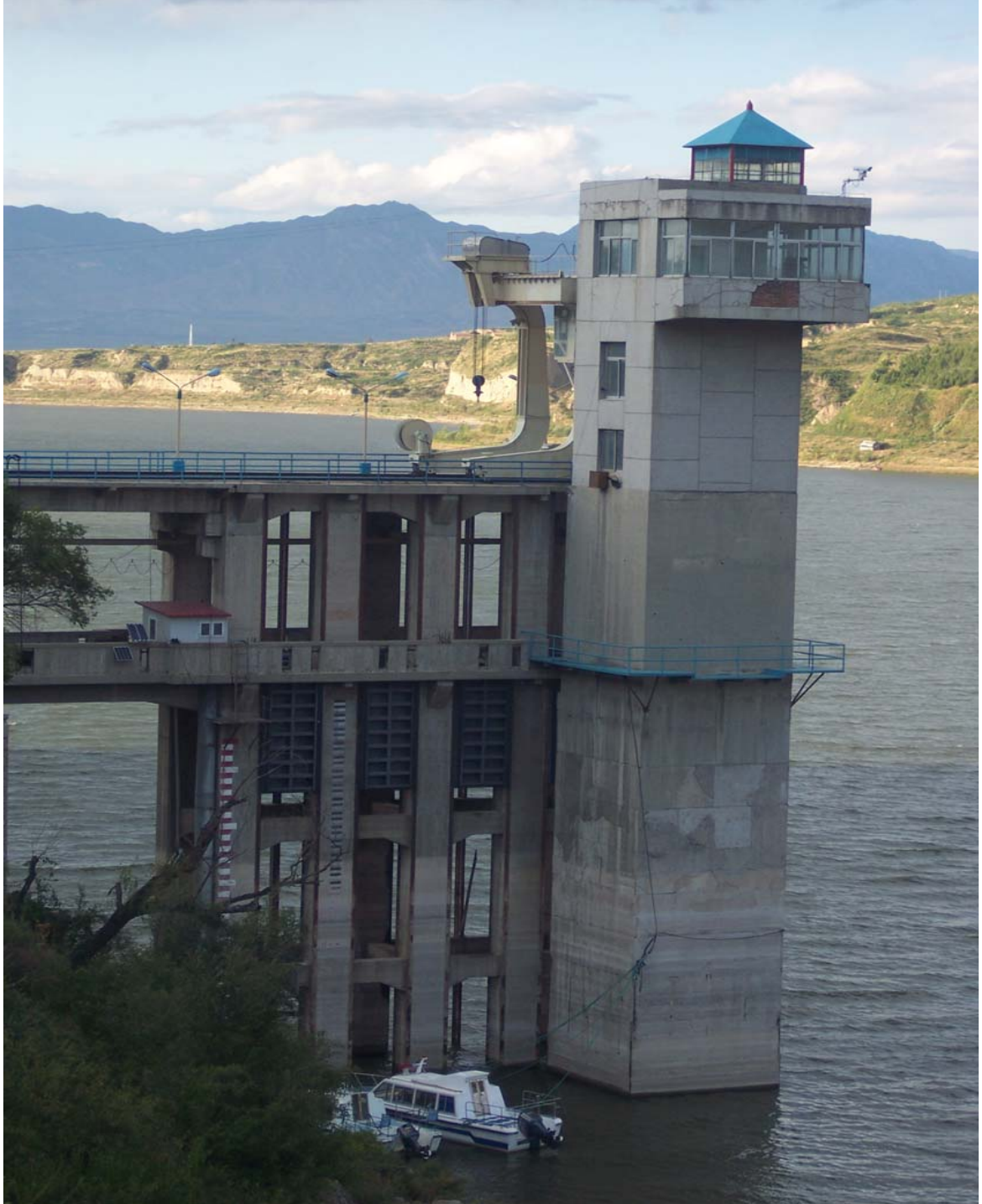

QuanTing Reservoir


QuanTing Reservoir

Quan Ting
Water Level
is
Severely
Depleted

(Photo: Murcott,
Sept. 2006)

QuanTing Reservoir Dam



No water in Quanting Reservoir spillway, hydro power plant cannot run

Reservoir Downstream of YongDing (Yang) near Beijing's Capital Steel Works

Capital Steel Works uses twice as much water per tonne of finished steel as do Shanghai mills and 4x as much as typical Western rate. (Smil, 1993)

Miyun Reservoir – drying up (Photo Credit: Wang Jian, 2006)

Beijing Municipal Water Treatment Works

(Wang et al, 2006)

	Capacity $10^4 m^3/d$	Location	Date	Source
No.1	4.2	NE suburb	1910	Groundwater
No.2	9	N. suburb	1949	Groundwater
No.3	39.6	NW suburb	1958	Groundwater
No.4	5.5	SW suburb	1957	Groundwater
No.5	3.0	NE suburb	1960	Groundwater
No.6	17.2	SE suburb	1959	Tonghui River & SE suburb irrigation channel

Beijing Municipal Water Treatment Works

(Wang et al, 2006)

	Capacity $10^4 m^3/d$	Location	Date	Source
No.7	2.2	S. suburb	1964	Groundwater
No.8	50	NE suburb	1979	Groundwater
No.9	150 = 390 mgd	N. suburb	1995	Miyun Reserv.
Tiancun shan	17 44 mdg	W. suburb	1985	Miyun Reserv.
Total	**297.7= 3M m3**	**=780 mdg**		

Beijing Water Works No. 9

- No. 9 is one of the largest water treatment plants in Asia - very similar size to the MWRA-Boston's Carroll Treatment Plant.

- No. 9 accounts for 60% of the surface water supply for Beijing (another source says 50%) (=36% of available water for Beijing), while the MWRA plants provides more water than is presently necessary (capacity larger than demand).

- Total capacity = 1.5 million m3 (about 400 million gallons)

Beijing Water Works No. 9
(Ministry of Water, 2007)

- Uses typical water treatment process train
  - coagulation/flocculation,
  - mixing,
  - filtration,
  - chlorination disinfection,
  - activated carbon filtration (a polishing step).

- No.9 Water Works constructed in three phases:
  - 1990 - the first phase put into operation
  - 1995 = Phase II
  - 2000 = Phase III
- Various components of the No. 9 plant are from the US and Germany.

Front Entrance

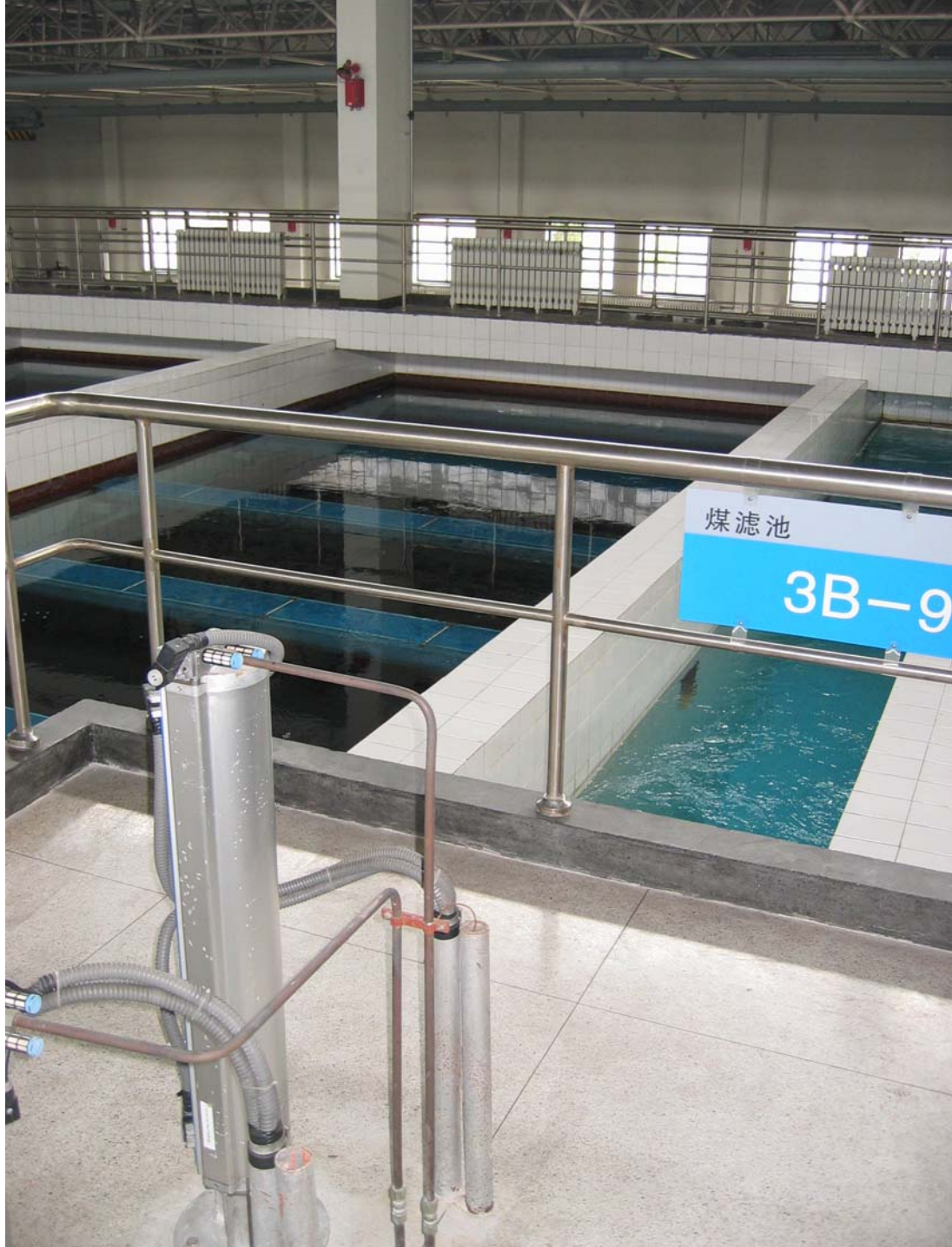
Beijing Water Works No.9

Activated Carbon Tanks

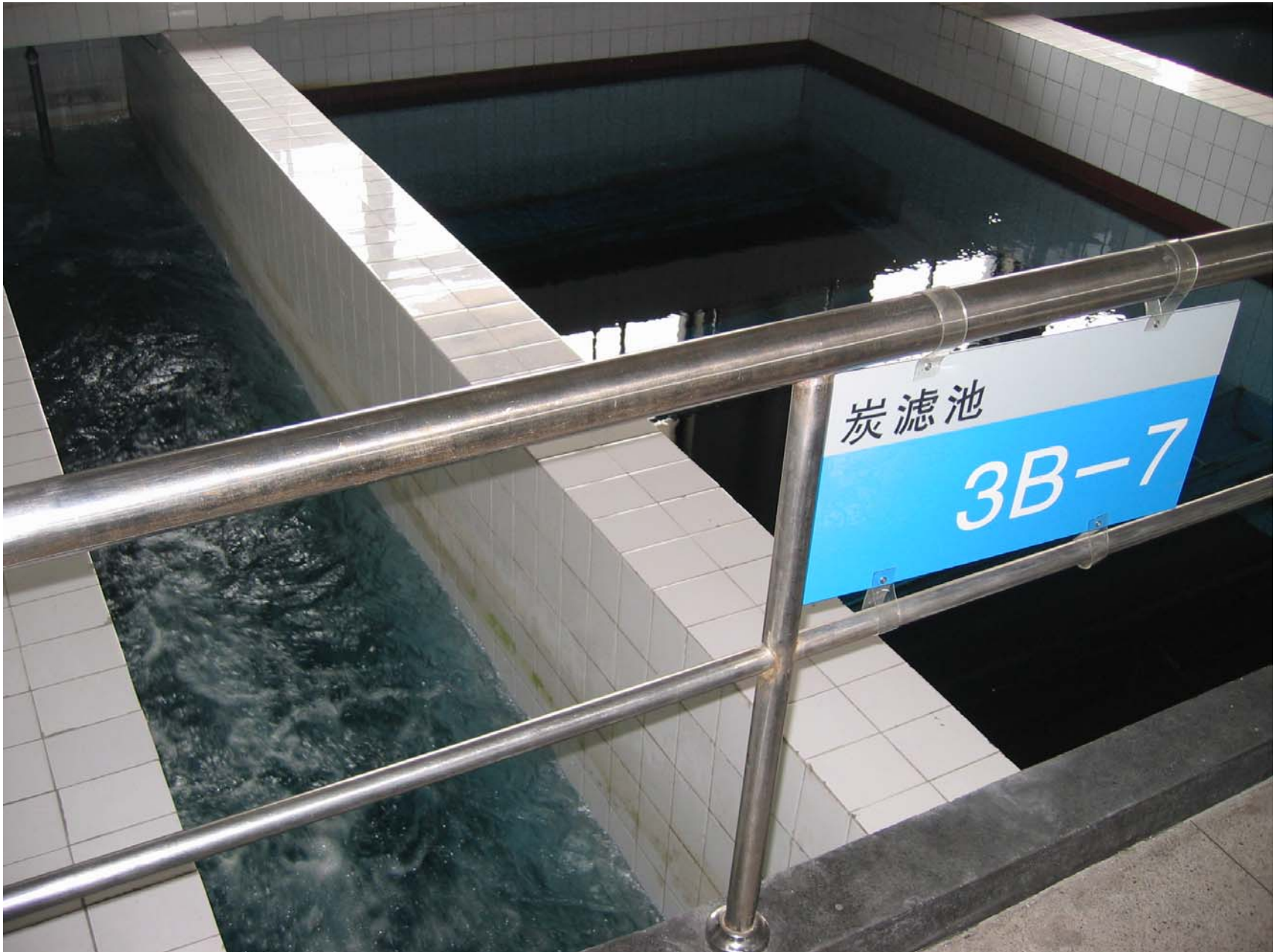
Beijing Water Works No. 9

Activated Carbon Filters

Beijing Water Works No. 9



Carbon Filters – Beijing Waterworks No. 9



No.10 Water Works

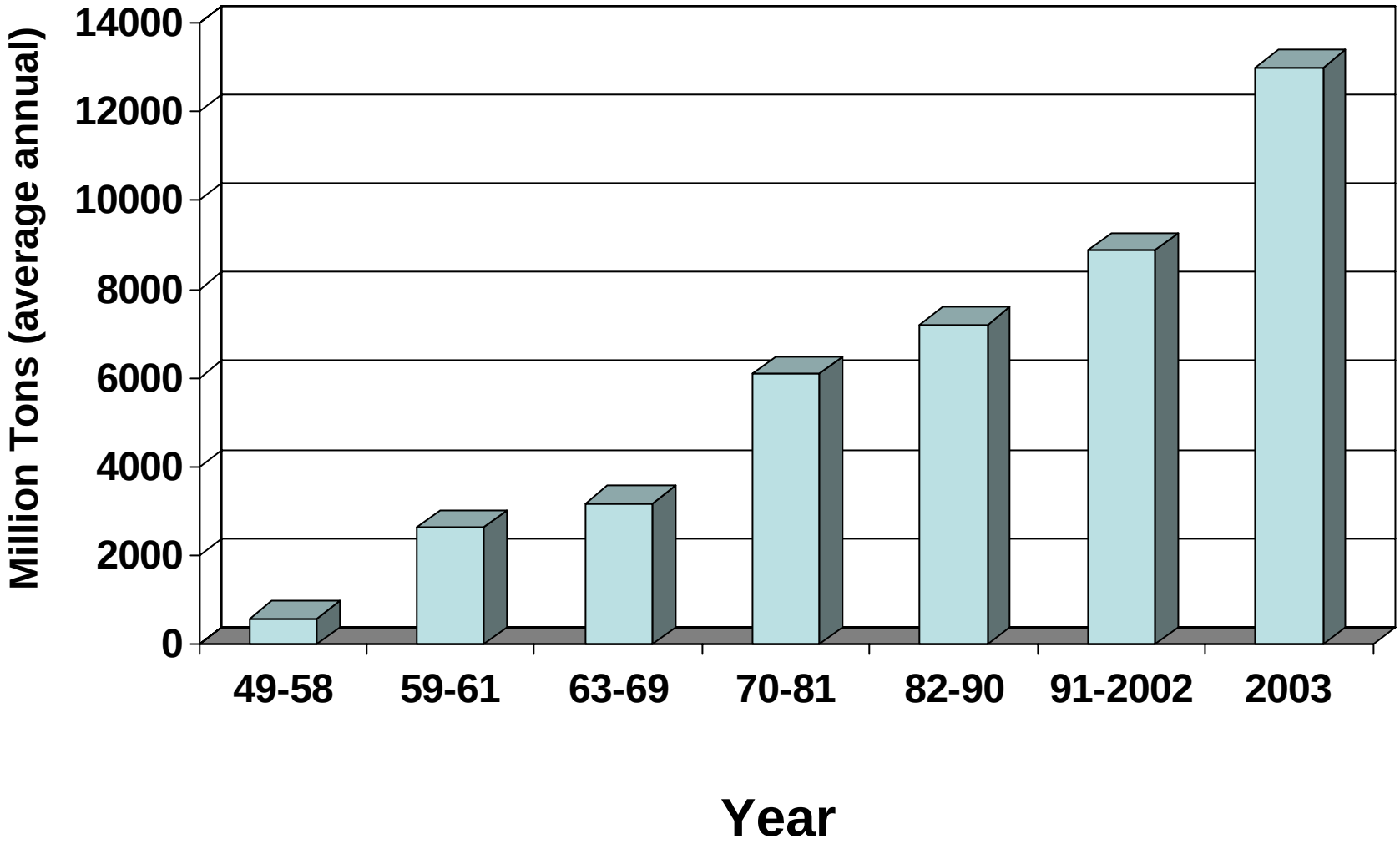
- Capacity = 1 million m^3/day (260 mgd)
- To be completed by 2010
- At that time, the treatment works will be providing 4 million m^3/day (1040 mgd) (=1.5 B m^3/year)

Pollution Concerns

- Lack of wastewater treatment
  - About 25 of domestic waste treated
  - Nearly half of population not hooked up to city's sewage system
- Industrial waste
  - Almost half discharged without any treatment
- Water supplies
  - Growing issues
  - Some reservoirs, such as Quanting, not drinkable
  - 17% of city wells found to have phenols, mercury, cyanide, chromium

Eve Hou and Garvin Hunter, Beijing Water: Causes, Effects, Solutions, 3x3 Project, http://www.chs.ubc.ca/china/

Beijing Wastewater Discharge (annual average in million tons)

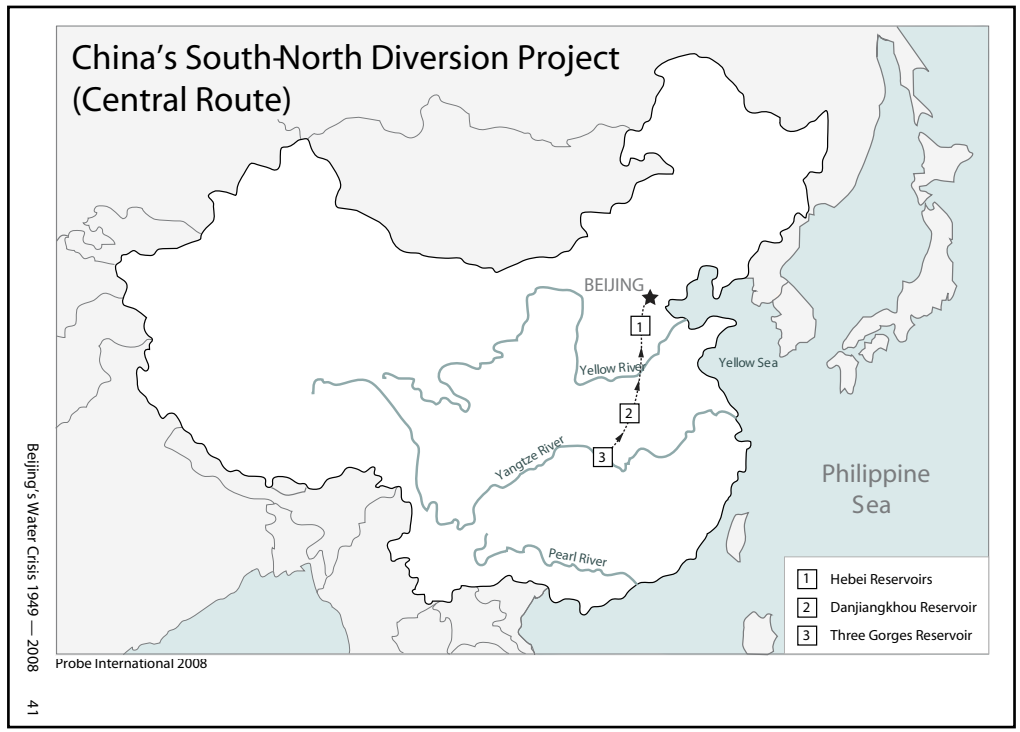


Wastewater Increase in Beijing

Year	Ave. Wastewater Discharge (million tons)
1949 – 1958	600
1959 – 1961	2,640
1963 – 1969	3,180
1970 – 1981	6,090
1982 – 1990	7,200
1991 – 2002	8,870
2003	13,000

South to North Water Transfer Project

- SNWT proposes to move 40-50 BCM of water through 3 canals: Eastern, Central and Western, from Yangtze to Yellow River and Beijing.
- Price = US$ 58B, more than 2x official price of the 3 Gorges Project
- Construction underway on the Middle Route (300 – 500 million m3 from Hebei in 2007)
- Construction underway on the Eastern Route, upgrading and extending the ancient Grand Canal (1 BCM by 2010)



Courtesy of Probe International. Used with permission.

Enough Water?

- Slow down economic growth?
  - Water intensive industries worry
- Safe yield for Beijing?
  - 1.8 billion cubic meter shortfall by 2010
    (conservative estimate)
  - Shortfall is over 1300 million gallons per day!
- South-North River Transfer
  - Enough water, but what is the full cost?
  - How much further will Beijing have to go for enough water?

Wang et al, Water Policy 8 (2006), 97-110

What is Beijing Doing?

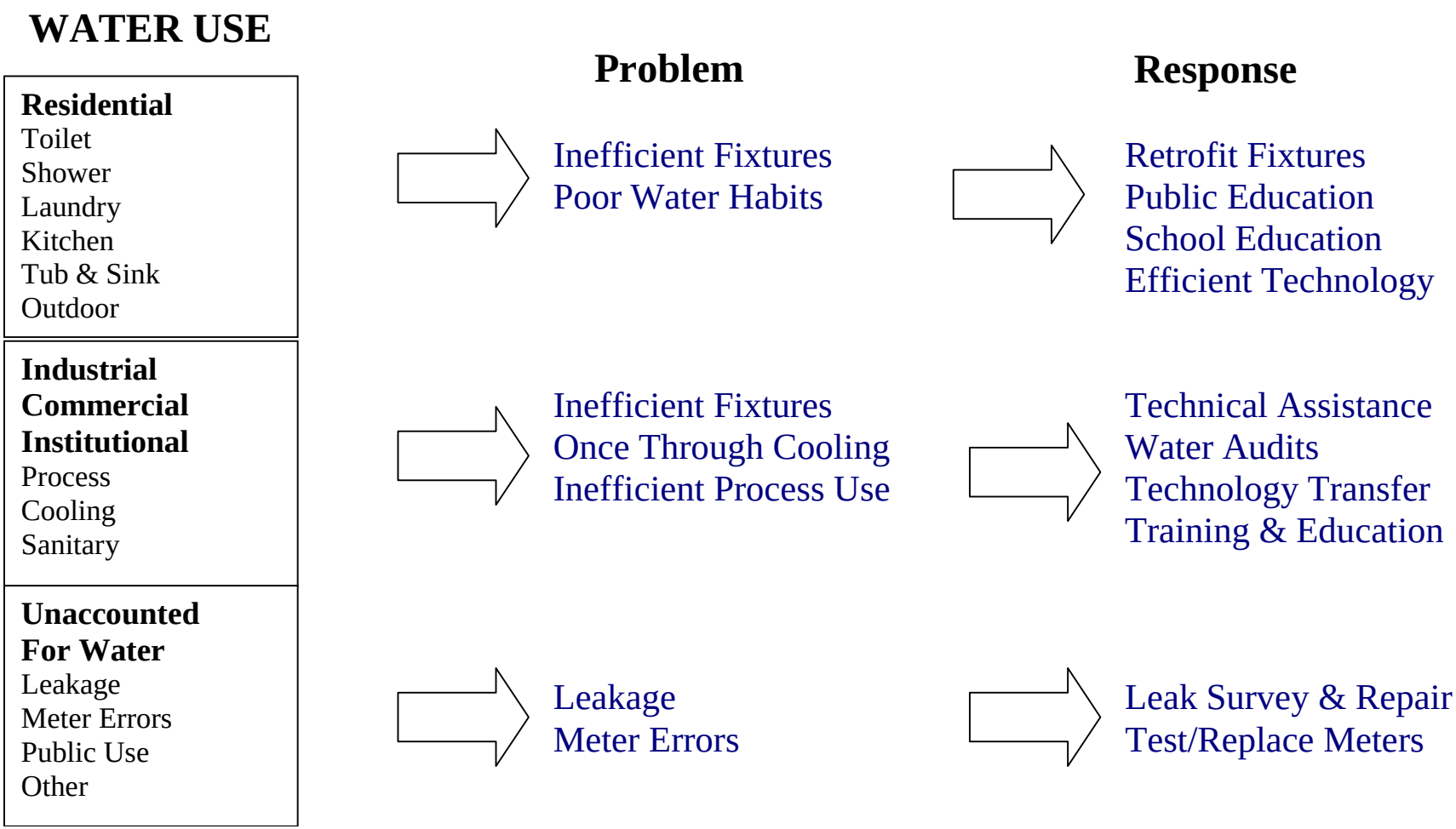
The 11th 5 year plan includes 3 major approaches to protect water resources (Ministry of Water, 2007):

1. Protect the environment around water resources.
2. Surface water, groundwater and wastewater reuse will be combined together [Note: this translation from the Chinese may be unclear…]
3. South-North Water Transfer Project.
   * Hebei Province: 300 – 500 million m3 (2007)
   * Yangtze River: 1 billion m3 (2010)

What Did Boston-MWRA Do?

- MWRA Board of Directors voted to try water conservation for a 3-year period to curb demand (11/1986) → 25 long and short term policies, including:
- Leak Detection, Repair and Metering
- Conservation and Demand Management
- Improved Use of Sources
- Water Supply Protection
- Management and Planning for the Future
- Outreach and Reporting

What Did Boston-MWRA Do? Demand Management Strategy



What Did Boston-MWRA Do? Multimedia Approach

Purpose	**Technique**	**Distribution**
Make consumers Aware	Bill Stuffers Messages on Water Bills Brochures Displays Public Service Announcements Press Releases	Utilities direct mail Community centers Town halls, Libraries Special events Radio, TV, Cable Local Media
Respond to Questions	Fact Sheets FAQ's Newsletters Speakers Bureau Resources Network Customer Service Training	On Request Workshops Community Meetings WEB site Employee
Facilitate Decisions	Personal contact Independent, credible sources Partnerships Newsletters	Workshops Community Meetings Customer hotline

What Could Beijing Do?

- Stronger control of all water and wastewater in city – both surface and groundwater
- Improve infrastructure
  - Drinking Water
    - New Water Works Plant #9
    - 1.5 million m^3 capacity
    - Chlorination, filtration, act. carbon
  - Wastewater treatment and reuse
  - Reclaimed water
- Increase price of water
- Divert water from agriculture to urban use
- Strict conservation program
- Reduce industrial use and waste, efficiency improvements
- South-North Water Transfer Project
- Other sources?

Are there lessons for Beijing from MWRA-Boston experience?

- Need more centralized control
  - Particularly ground water
- Conservation
  - Doing enough? (Wang et al article)
  - Need strict guidelines
- Reduce industrial use / improve efficiency
  - Use reclaimed (brown) water
- Reduce Unaccounted for Water

Beijing - Conclusions

- Water stressed city
- Rising population, rapid industrialization, rising demand
- Can MWRA lessons and policies be applicable in Beijing?

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