Guangdong-Hong Kong-Macau Greater Bay Area
Physical Geography

Lincoln FOK
The Education University of Hong Kong
Introduction

The Physical Environment
The Delta
The Water

A PLACE WITH A MARITIME ORIGIN
清朝
珠三角航海圖

珠三角航海圖集 p.71
Provincial atlas of the great Qing Dynasty
(1754-1760) Courtesy USA Library of Congress, Geography and Map Division
Belt & Road Initiative
The Pearl River Delta Megacity

Will it be the death of Hong Kong?

The Pearl River Delta is slowly growing into a single colossal megapolis. And as controversy reigns over the continued urban development into the HKSAR’s northeastern territories, we dissect the future of the extravagant sprawling metropolis and see how its emergence will affect — and perhaps eventually kill — Hong Kong. By Samuel Lai
The Physical Environment

DICTATES SPATIAL PATTERNS
### Mountain Ranges

<table>
<thead>
<tr>
<th>River</th>
<th>Drainage Area (km²)</th>
<th>Discharge (Mm³/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>353,120</td>
<td>233,000</td>
</tr>
<tr>
<td>North</td>
<td>46,710</td>
<td>52,100</td>
</tr>
<tr>
<td>East</td>
<td>27,040</td>
<td>26,100</td>
</tr>
<tr>
<td>Murray (AU)</td>
<td>1,061,469</td>
<td>24,188</td>
</tr>
</tbody>
</table>
Humid subtropical
Subtropical dry winter
Zones: a matter of (spatial) scale
100 – 1000 km
Cfa / Cwa **Humid subtropical** / subtropical dry winter

Controlling factors: Latitude, sea-land location, topography, atmospheric circulation
Climographs

Zhaoqing - Cfa

Hong Kong SAR - Cwa

\[
\frac{\text{min}(\text{precip.})}{\text{max}(\text{precip.})} = 11.4\%
\]

6.6\%
Monsoonal Influence
Pearl River Delta Precipitation 1959 – 2000

Annual: 1,845 mm
Accumulated daily avg. temp. $>10^\circ$C (degree-day)

$>7000$ °C-day
Vegetation zones of China (Sun et al. 2008)

Subtropical evergreen broadleaf Monsoon forest
紅壤 Red earths
水稻土 Paddy soils
High Temp.; high Precip.
Deep weathering profile
Leaching
Cultivation history
Pearl River Delta Megacity

- Navigation (trade)
- Land (flat)
- Water (River)
- Food (Climate)

The largest urban area in the world in 2010 (World Bank 2015)
Figure 2.10  The 25 largest urban areas by population and land area, 2010

42 mil. pop
7,000 km²
(excl. HKSAR)

Canton Tower & CBD of Guangzhou (Tianhe)
Jan 1979 Landsat 3, false-colour

- Guangzhou
- Foshan
- Dongguan
- Shenzhen
Jan 2003 Landsat 7, false-colour
The Delta

which laid the foundation
Delta: Works of river into the sea

- Lowering velocities

- Zone of mixing

- Density:
  - Lowest
  - Highest

- Plan view

- Deposition of bed load

- Flocculation of suspended load

- Axial cross-section

- Basin
Delta deposits

Progradation 進積 Vs
Retrogradation 退化

Delta top facies:
channel sands and delta plain muds

Mouth bar sands

Prodelta muds

Marine shelf deposits

Topset - essentially flat-lying gravels

Foreset - beds of sand and gravel dipping at 10°–25°

Bottomset - gently inclined fine-grained sediment

Coarsening upwards

Delta slope 1–2°
Wave-dominated
Mouth bars reworked into shore/parallel sand bodies and beaches

River-dominated
Significant delta-lobe progradation
Mouth bars that are reworked into elongate sand bodies perpendicular to the shoreline

Tide-dominated

(a) Nile

(b) Mississippi

(c) Rhone

(d) Ganges-Brahmaputra

(Nichols, 2009)
Trifurcation of mouth bar under different tide amplitudes

Hoitink et al., 2017
Imbalanced development:

89.9% and 95.8% of discharge & sediment respectively are carried by the West and North Rivers.

6000 – 2500 aBP
Mud-silt dominated

2500 aBP – now
Sand dominated

No delta formation
SW-SCC; NE-WCC

Li et al. (2001)

Solid geology
Classification of River Deltas

After Galloway 1975
The Fourth Control

寶安沿海發展

廣州
龍穴島
南沙港

天鯤號
The Water
AND WHAT SHE CARRIES
Total Renewable WR (1960-2007)

Israel 1.7 km³

Kuwait < 0.1 km³

Data: earthtrends.wri.org
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Per capita Renewable WR (2007)

World average 8210 m³/cap/yr
China: 26% of global average.
Water Resources Zonation in China

Est. 2002
10 “first-level” regions
80 “second-level” zones
214 “third-level” zones
10 Second-level Zones in the Pearl River Region

Pearl River alone 415 000 km²
East River 32 000 km²
Water Resources per capita

<table>
<thead>
<tr>
<th>Area</th>
<th>m³/cap/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>8210</td>
</tr>
<tr>
<td>China</td>
<td>2125</td>
</tr>
<tr>
<td>Northern China WR</td>
<td>900</td>
</tr>
<tr>
<td>NW Rivers</td>
<td>4660</td>
</tr>
<tr>
<td>Songhua R.</td>
<td>2330</td>
</tr>
<tr>
<td>Liao R.</td>
<td>909</td>
</tr>
<tr>
<td>Yellow R.</td>
<td>645</td>
</tr>
<tr>
<td>Huai R.</td>
<td>455</td>
</tr>
<tr>
<td>Hai R.</td>
<td>290</td>
</tr>
<tr>
<td>Beijing</td>
<td>326</td>
</tr>
<tr>
<td>Lingxia</td>
<td>190</td>
</tr>
<tr>
<td>Israel</td>
<td>240</td>
</tr>
</tbody>
</table>

Data: Wang (2010) 中國水資源問題
Bay Area, water resources per capita

Source: China Water Risk. Water resources and water use figures are based on NBSC, Guangdong Statistical Yearbook 2016 & Hong Kong WSD Statistics. Base maps derived from Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences.
Seasonal Precipitation Variability

Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000
National total supply 591 km³. 81% from surface waters

S: 96% from surface water

N: 63%

- Hai R.: 33%

Source Contribution of Water Supply 2008

Water Use in China


2008 Domestic consumption: 150 L/cap/d
Water Use by "Sector", 2008


<table>
<thead>
<tr>
<th></th>
<th>National</th>
<th>Domestic</th>
<th>Industry</th>
<th>Agriculture</th>
<th>Ecological</th>
</tr>
</thead>
<tbody>
<tr>
<td>km³</td>
<td>73</td>
<td>140</td>
<td>366</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>12</td>
<td>24</td>
<td>62</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Sum of Fields

- NW Rivers
- SW Rivers
- SE Rivers
- Yellow R.
- Hai R.
- Huai R.
- Songhua R.
- Liao R.
- Pearl R.
- Yangtze R.
- Domestic
- Industry
- Agriculture
- Ecological
2015 Water Use Mix: PRD vs Guangdong vs China

Source: China Water Risk based on NBSC and Guangdong Statistical Yearbook 2016
% Water Utilization by Region

- Songhua R.: 27.6%
- Liao R.: 40.7%
- Hai R.: 100.3%
- Yellow R.: 53.4%
- Huai R.: 67.1%
- Yangtze R.: 19.6%
- SE Rivers: 12.8%
- Pearl R.: 18.6%
- SW Rivers: 1.9%
- NW Rivers: 50.3%

National: 20.8%
Channel Bed Changes (mm/year)

Lu et al. 2008

Link with the cause!
0.3 %‰ (300 mg/L) salinity front invaded inland.

Main causes:
- High tide
- Wind direction
- Sea level change
- Low discharge / drought (climate change?)
- Channel dredging

Salinity front during the dry season
Dongjiang salt water limits with time  Jia et al. 2007
Salt-tides 鹹潮
(saline intrusion)

Saline intrusion: invasion of seawater into freshwater systems

Occurs in all estuaries where freshwater systems meet seawater

Occurrence in Pearl River estuary: Dec – Feb

2005, 2007 & 2009 major salt-tide episodes affected water supply of ten millions

More frequent & occur earlier, affecting cities like Dongguan, Zhuhai, Zhongshan, Macau and Guangzhou.
Salinity
Total dissolved concentration predominated by Sodium (Na) & Chloride (Cl)

<table>
<thead>
<tr>
<th>Type</th>
<th>Salinity [‰]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>0 – 0.5</td>
</tr>
<tr>
<td>Brackish</td>
<td>0.6 – 30</td>
</tr>
<tr>
<td>Saline</td>
<td>30 – 50</td>
</tr>
<tr>
<td>Brine</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>

WHO Drinking Water Standard
- 250 mg Cl / L (0.25 ‰)

Exceedance not suitable for people with diabetes, heart disease & high blood pressure, typically elderly

> 400 mg/L not suitable for everyone

**Pollution** = exceedance of standard
Water Quality

Sources of water pollution

- **Industrial discharge**
  - e.g. metallurgy, concrete, food, plastic, leather manufacturing, petrochemical industries.

- **Domestic discharge (58% of discharge in 2008)**
  - Low treatment rate. National municipal sewage treatment rate only 63%.

- **Agricultural runoff**
  - Non-point source
  - Mainly nutrients and agrochemicals.

**Major pollutants: organic**

- COD, NH$_3$-N, BOD$_5$, DO & volatile phenol.
- Metals in some places.

**Number of city without sewage treatment.**

<table>
<thead>
<tr>
<th>Year</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>205</td>
</tr>
<tr>
<td>2007</td>
<td>168</td>
</tr>
<tr>
<td>2008</td>
<td>139</td>
</tr>
<tr>
<td>2009</td>
<td>88</td>
</tr>
</tbody>
</table>

Source: SEPA 《全國城市環境管理與綜合整治年度報告》
Trend of Waste Water Discharge

- NW Rivers
- SW Rivers
- Pearl R.
- SE Rivers
- Yangtze R.
- Huai R.
- Yellow R.
- Hai R.
- Liao R.
- Songhua R.

- 14.9 billion tons
- 3.7 billion tons
GB 3838-2002 Environmental Quality Standards for Surface Water

<table>
<thead>
<tr>
<th>Grade</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Waters of headwaters &amp; natural reserves</td>
</tr>
<tr>
<td>II</td>
<td>Habitat for rare species and spawning grounds</td>
</tr>
<tr>
<td>III</td>
<td>Contact recreation &amp; aquaculture</td>
</tr>
<tr>
<td>IV</td>
<td>Industrial uses and non-contact recreation</td>
</tr>
<tr>
<td>V</td>
<td>Agricultural uses and landscaping</td>
</tr>
<tr>
<td>Inferior V</td>
<td>(劣V) Lost all functions</td>
</tr>
</tbody>
</table>

- 24 “basic” parameters (T, pH, DO, COD, BOD, nutrients, metals, organic pollutants, E. Coli etc.).
- 5 “additional” parameters for sources of centralized intake.
- A further 80 “selective” parameters for sources of centralized intake to be specified by the local environmental authority.
Water Quality

![Water Quality Chart]

- 黄河
- 松花江
- 海河
- 浙闽片河流
- 西南诸河

Legend:
- 劣V类
- IV、V类
- I ~ III类
WQ in Pearl R. 2014

Grade II – Blue
Grade III – Green
Grade IV – Yellow
Grade V – Orange
Inferior V - Red

Pearl River Basin (% of monitoring points)

<table>
<thead>
<tr>
<th>Year</th>
<th>Grade I-III</th>
<th>Grade IV-V</th>
<th>Grade V+</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>95%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>2011</td>
<td>95%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>2012</td>
<td>95%</td>
<td>4%</td>
<td>1%</td>
</tr>
<tr>
<td>2013</td>
<td>95%</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>2014</td>
<td>96%</td>
<td>4%</td>
<td>1%</td>
</tr>
<tr>
<td>2015</td>
<td>98%</td>
<td>4%</td>
<td>1%</td>
</tr>
</tbody>
</table>

PRD (2015): 24%
Dongjiang (2015): 11%

Source: China Water Risk based on MEP Annual State of Environment reports (various years) for the Pearl River, and Guangdong Water Resources Report 2015 for the PRD and Dongjiang
Hong Kong Local Water Resources “Guesstimation” (:

Data:
Precipitation 3000 mm
Land area: 1076 km²
Runoff coefficient = 0.6
2009 Population 7 million

\[
\frac{2 \times 1,076,000,000}{7,000,000} = 307 \text{ m}^3/\text{cap/yr}
\]

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The East River

Area = 35,340 km²
Annual WR = 33 km³

3 major reservoirs
- Fengshuba 1973
- Xinfengjiang 1960
- Baipenzhu 1992
- Total storage capacity to annual discharge ratio: 0.78 (0.15 for whole Pearl River, Zhang et al. 2008)

14 low-head dams along main stream

Dongshen water supply scheme 東深供水工程 (2003)
Lee et al. (2007) applied WQ modelling

Qiaotou min Q requirement in 2010 = 467 m$^3$/s

- 150 m$^3$/s (4730 Mm$^3$): water demand
- 317 m$^3$/s: minimum flow for maintain a grade II standard (9997 Mm$^3$)
- Associate with exceedance probability of 55%

2008: Guangdong government water allocation plan.

- Maximum water intake for water supply = 10.7 km$^3$ = 338 m$^3$/s!!
- Doubled the amount quoted by Lee.
Estimated change in aridity (PDSI) under the SRES A1B scenario

Intensify of aridity in most of Am., S. Europe, Middle East, large areas in Africa, Australia & SE Asia.

Drought becoming more widespread & may return in the coming decades!

Hydrological Hazards

Hydrological extreme conditions
Magnitude and frequency
Drought: deficiency in water supply
Flood: Physical overflow of water (not in response to demand!)
(Hewitt 1997)

X: Precipitation / Soil moisture / Discharge etc.
Flooding in Bay Area

Last 40 years, there have been 190 flood events (Huang et al, 2004)

Many causes:

- Rain
- Sea level rise
- Shape of coast
- Astronomical tide
- Storm surge
全市易内涝点示意图

1. 易内涝点：天寿路广深铁路桥底
   责任单位：天河区政府

2. 易内涝点：华南师范大学周边（含五山路、天科路、天河北路、中山大道）
   责任单位：天河区政府

3. 易内涝点：员村一横路加气站对出路段
   责任单位：天河区政府

4. 易内涝点：广园快速路食博会正门对出路段
   （东往西方向、北行科韵路桥底掉头位）
   责任单位：天河区政府

5. 易内涝点：开发大道（夏园）立交
   责任单位：黄埔区政府

Guangzhou

2016 May 11, 93mm / 1 hr

2010 May 07, 213mm / 12 hrs
Change in average precipitation (1986–2005 to 2081–2100)
Global Sea Level
Rate at 3.2 ± 0.4 mm per year
Representative Concentration Pathways: Scenarios for carbon dioxide emissions; Resulting atmospheric concentration in 2100

- **RCP2.6**: 430 – 480 ppm
- **RCP8.5**: >1000 ppm

Melting of Greenland Ice Sheet = 7.2 m

*IPCC AR5 (2014)*
Tidal range 6 – 9 m+
Funnel-shaped estuaries
Tidal bore (潮湧)
Astronomical Tide
2015 Astronomical tide

【大紀元6月25日報導】（中央社記者林於國香港二十五日電）廣東西江、北江洪峰直逼珠三角，天文大潮也使海水倒灌，珠江廣州河段水位昨天急速上漲，並且出現自一九一五年有紀錄以來的最高水位。市內八區共有十七個街鎮出現淹水，廣州市地標五羊雕像旁的山坡亦出現山泥傾瀉，增城七千多間房屋泡水，當地學校要停課三天。
Storm Surge

Storm surge and high waves caused by tropical cyclone

Mean Sea Level
Chart Datum

Mean Sea Level
Chart Datum

Typhoon Hato, Aug 2017
DROWNING
Cities with the 10 highest annual flood costs by 2050

RUNNERS-UP
- Jakarta, Indonesia $1.7bn
- Abidjan, Côte d'Ivoire $1bn
- Chennai, India $0.93bn
- Surat, India $0.92bn
- Zhanjiang, China $0.89bn
- Tampa, USA $0.85bn
- Boston, USA $0.79bn
- Bangkok, Thailand $0.73bn
- Xiamen, China $0.72bn
- Nagoya, Japan $0.64bn

Map by Tim McDonnell
Source: Hallegatte et al.
Thank you!

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