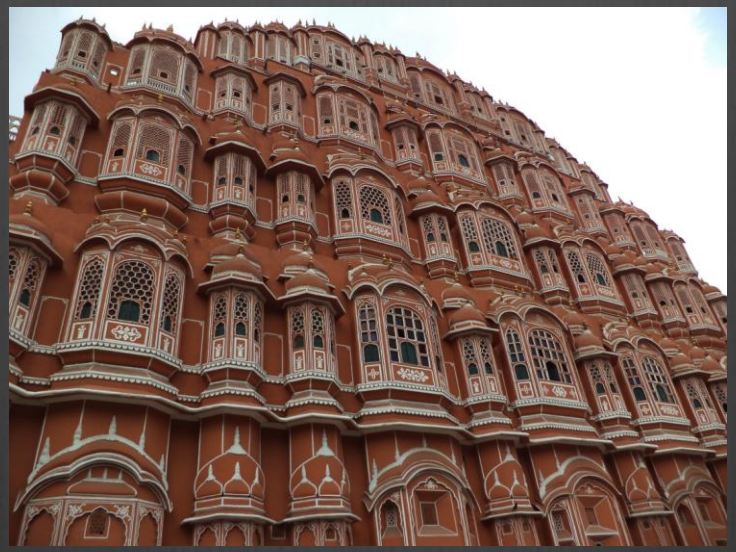
Water Scarcity in Jaipur, Rajasthan, India



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Northwestern University
Research in Jaipur in Summer 2013

January 2014

Summary of Work

- Two engineering students from Northwestern University, Kathleen Roberts & Michael Reiner, traveled to Jaipur in the Summer 2013 to study the water resource and sanitation system.
  - Investigated conditions by touring various critical sites, conducting literature searches, & meeting with professionals in the field of water issues in Jaipur.
- Although Jaipur receives only an average of 600 mm of precipitation per year, mostly in the monsoon months of June-September, we believe that:

Management issues exacerbate Jaipur's water scarcity challenges.

Introduction

- Jaipur ranks 10th among Indian megacities with an annual growth rate of ~ 5% between 2001 and 2011, and a population of 3.1 million.
- The city's economy is primarily based on trading, administration, tourism activities, & local handicrafts industries.
- Jaipur is a popular tourist destination, with about 3000 tourists visiting the city daily.

Introduction

- Jaipur depended on the Ramgarh Dam as its surface water source throughout the 1900s, but this became a non-viable source in the late-1980s/early-1990s, leading to a shift to complete dependence on groundwater & thus, a rapidly depleting aquifer.
- Jaipur is currently experiencing growing water scarcity and diminishing drinking water sources.
  - Jaipur relies extensively on groundwater and a single surface water source, the Bisalpur Dam, which is located 120 km southwest of Jaipur & is shared with Ajmer and Tonk District villages.

Ramgarh Dam Area, July 2013

Source: Personal Photographs

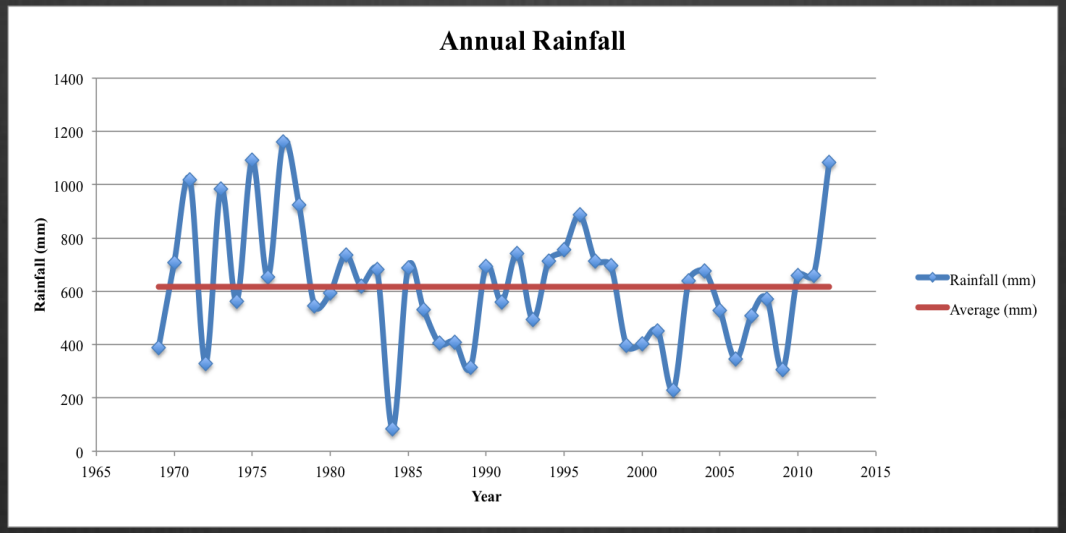
Introduction

- There are tens of thousands of unaccounted for wells throughout Jaipur, since tapping of groundwater is still a landowner's right.
- There is a lack of adequate water supply and demand accounting, both in terms of government water supply and private water supply.
- In addition to water scarcity, degradation in quality of both surface and groundwater sources is of great concern.

Physical Geography of Jaipur

- Jaipur is located in the semi-arid zone of India, which is characterized by high temperatures, low rainfall, and a mild winter.
- The average annual rainfall of Jaipur is about 600 mm.

Annual Rainfall of Jaipur:



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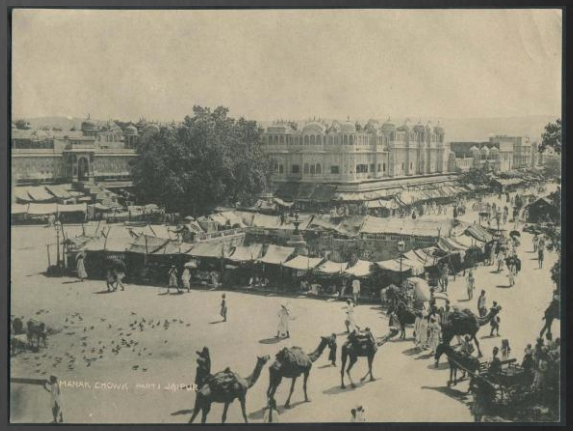
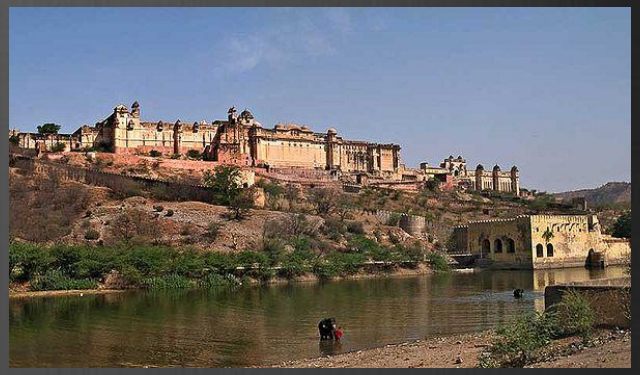
Linking Jaipur's History to its Water Management



- Jaipur is the first planned city of India.
  - Water security was considered in its design.
- The Old City continued to benefit from the original natural water systems in place until the 1930s when the population of Jaipur exceeded the capacity of the Old City.
  - The city soon had to turn to reservoirs located outside the immediate reaches of the city.
- Compounded by a lack of infrastructure (e.g., sewage systems, water piping, or drainage systems) & rapid growth, which defied any unified government planning, Jaipur's water security and supply began to deteriorate.

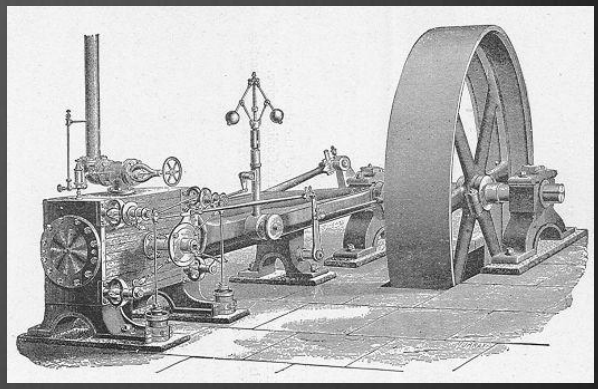
http://www.columbia.edu/itc/mealac/pritchett/00routesdata/1700_1799/jaipur/jaipurcity/jaipurcity.html

Jaipur's Early History



- Before the founding of Jaipur in 1727 by Maharaja Jai Singh II , Amer, located 9 kilometers north of Jaipur, was the capital of the then-state.
  - Amber did not have enough space for growth and suffered from water scarcity.
- Jaipur was planned to support a population of 150,000 people over an area of 1658 acres (or 6.7 square km).
- The early water supply system of Jaipur initially relied upon groundwater
  - Given Jaipur's topography, drainage patterns allowed for groundwater recharge.

Jaipur's Early History



- Amanishah Nala later provided a surface water source transporting water through a canal and collecting this water into kunds, though groundwater supplied the majority of water supply.
- The Amanishah Nala was further tapped in 1874 and utilized steam engines to pump water and supply Jaipur through a pipeline network.
- Soon after the damming of the Amanishah Nala, low inflow and silting of the dam reduced its capacity

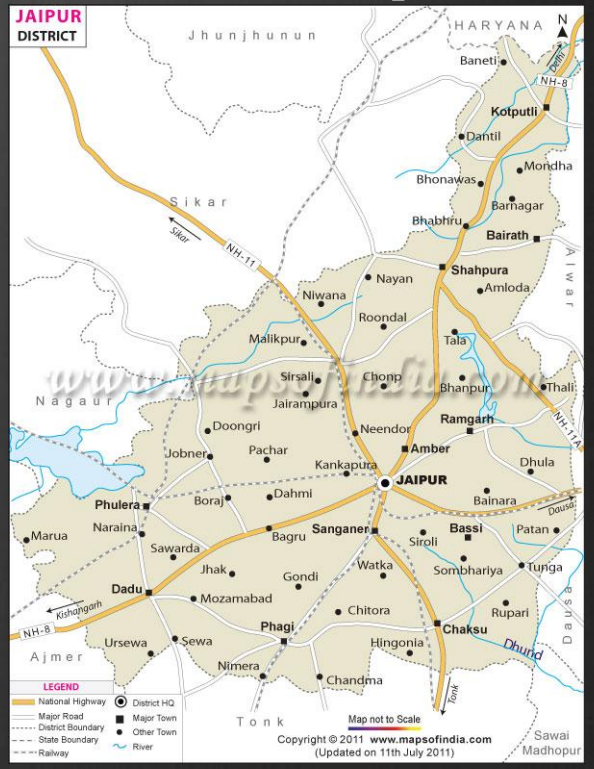
Growth and Urbanization Pre-Independence

- In the early 1900s, with population exceeding a lahk, the need for augmentation and expansion of the existing water supply scheme was felt.
- Compounding the increasing water demand, the Amanishah Nala was considered inefficient for further tapping due to recurring droughts.
- Emergency measures were taken regularly through installation of wells at the Amanishah Nala.

Growth and Urbanization Pre-Independence: Ramgarh Dam

- In 1903, a large reservoir and dam, named Ramgarh Dam, was constructed 30 kilometers northeast of the Jaipur & depended on inflow from the Banganga River.
  - Ramgarh Dam initially used for irrigation purposes in the surrounding villages.
  - With the advent of power generation in 1925 in Jaipur, a scheme was developed to actually bring this water to Jaipur.
- By 1931 Ramgarh Dam supplied water to Jaipur, although household piped water supply was not common and was only available to well-to-do families. Many localities did not have a public distribution system, and thus reliance on wells was still extremely common.

Map of Jaipur District (View of Ramgarh in relation to Jaipur)



Source: 13

Growth & Urbanization Pre-Independence

- The walled city became very congested in the early 1900s & the expansion of a modern Jaipur beyond the walled city became the dream of Maharaja Sawai Man Singh II.
  - 5 residential colonies, recognized as the first residential development outside of the Walled City, were planned: Adarsh Nagar, Banipark, C-Scheme, New Colony, Fetah Tibba.
- Development efforts were made in the 1940s to make Jaipur a center of industry and trade.

Growth & Urbanization Post-Independence

1947 - Train to Pakistan

- During the 1940s the population of Jaipur began a rapid increase due to the partition of India in 1947, which lead to the immigration of refugees from Pakistan, and the declaration of Jaipur as the capital of the newly merged Rajasthan State in 1949.
- With a government eager to satisfy the immediate needs of its residents, city planning and infrastructure were neglected.
- The original symmetry, order, and design of the city were compromised in order to allow for the rapid influx of people.

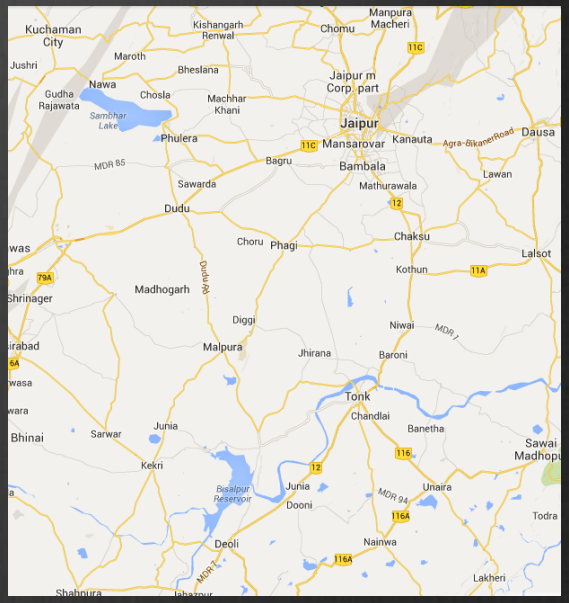
Growth & Urbanization Post-Independence

- During its rapid, pre- and post-independence urbanization, Ramgarh Lake was the main source of water for Jaipur.
  - Various augmentation schemes were implemented throughout this time to increase the supply capacity to Jaipur.
  - In the 1980s, Ramgarh started to show signs of excessive drawdown & gradually silted up to 14 ft., which greatly reduced its storage capacity.
- The government attempted to find another source of water supply in 1989 by sanctioning a water supply scheme to bring 18 million liters per day from the Bandi basin 20 km away from Jaipur. However, due to resistance from local people, this scheme could not be implemented.
- By 1999, water was no longer reaching Ramgarh Dam at all.

The 1990s to Today

- The rapid depletion of Ramgarh in the 1980s & 1990s led to a shift to and heavy reliance on groundwater sources.
- The Bisalpur Dam was commissioned by the Rajasthan government in the mid-1990s after other investigated sources were found to be inefficient. Bisalpur Dam is located in the Tonk District of Rajasthan, over 150 km from the center of Jaipur, & provides water to Tonk, Ajmer, and Jaipur.
- The transmission of water from Bisalpur Dam to Jaipur began in 2009.

Map of Jaipur & Bisalpur Reservoir

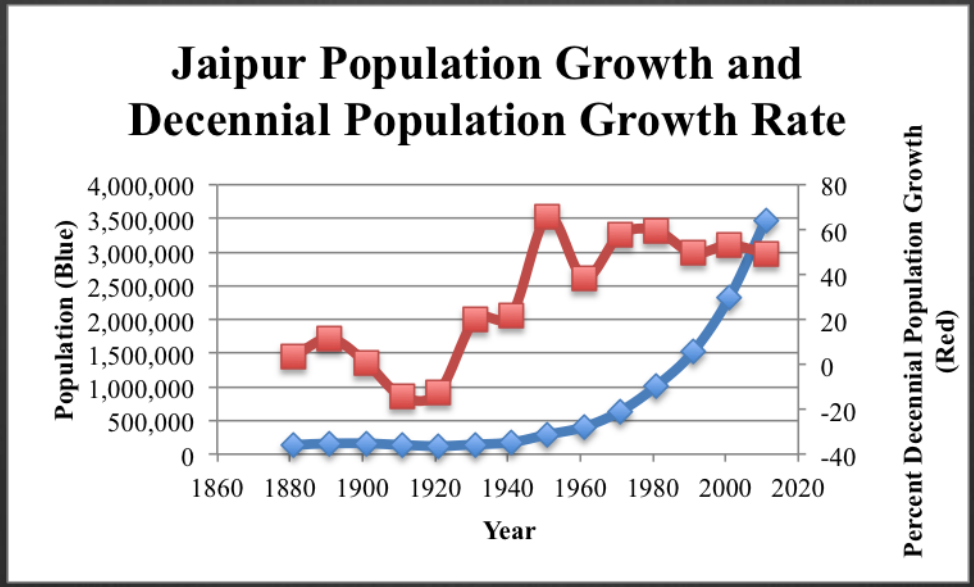


Source: 14

Urbanization & its Impacts

- Rapid population growth, especially since post-independence, resulted in a vast expansion of the city limits of Jaipur.

Jaipur City- Decadal Population Growth (1871-2011)



Source: 3, 17

Urbanization and its Impacts

- Urban Impact on Hydrology
  - There are as many as 518 rivulets originating from the Aravalli Hills: 398 1st order streams, 92 2nd order stream, 25 3rd order streams, & 3 4th order streams.
  - Many natural streams began to be used for dumping garbage. Due to expansion, 150 streams with 113 of 1st order, 37 of 2nd order, and 10 of 3rd order are blocked or have been filled for construction purposes.

Urbanization and its Impacts

- Urban Impacts on Surface Waters
  - Degradation in Water Quality
    - Industrial processes in and around the city have greatly and negatively affected the quality of surface waters in Jaipur.
      - Amanishah Nala has become unsightly and foul smelling due to the discharge of industrial wastewater to its storm water drainage network.
      - Decreased water quality causes increased health risks and increased spending on health care.
      - These conditions also allow for an increased risk of pollution of shallow aquifers

Urbanization & its Impacts

- Urban Impact on Groundwater
  - Jaipur's groundwater supply has diminished to a critical limit, with more than 500% overexploitation in some areas & severe degradation in quality.
    - Lack of regulation of tube wells has also compounded the problem.
      - With an estimated 20,000 private tube wells within the city, compared to approximately 2,000 Public Health Engineering Department controlled tube wells, the regulation and monitoring of groundwater extraction are nearly unachievable.

http://www.globaleducation.edu.au/2365.html

Urbanization & its Impacts

- **Urban Impact on Groundwater**
  - Depletion
    - With increasing population, increasing dependence on groundwater
    - Loss of forest lands, agricultural fields, pasturelands, & open wasteland due to urbanization, building of roads, houses, and commercial complexes has reduced recharge areas around Jaipur.
  - Degradation
    - The overexploitation of groundwater concentrates the inherent salts, fluorides, chlorides, and other chemicals already found in the water.
    - The seepage of sewage water into surface water sources has further degraded the water.

http://education.nationalgeographic.com/education/media/housing-jaipur/?ar_a=1

Urbanization and its Impacts

- Urban Impact on Natural Gradient and Flood Area
  - Rapid urbanization of Jaipur, increase in paved area and decrease in open, recharge areas land has resulted in an increase in local urban flooding.
  - During rapid urbanization, the drainage system of Jaipur was given little attention.
    - New development and residential colonies developed over the bed of the drainage patterns. As well,
    - construction often involves flattening of the land disrupting the natural topography and thus drainage of the area.

Current Supply Scheme and Management

- The water supply from the government is intermittent and the average duration of running water is 90-120 minutes per day.
- General inadequacy in water availability can be found in:
  - calculations of supply and demand that reveal deficits in government water supply
  - high unaccounted for water losses
  - drops in supply pressure due to large quantities of water released in short durations or the depletion of groundwater affecting pressure in tube wells
  - issues with water metering and fees

Current Supply Scheme & Management

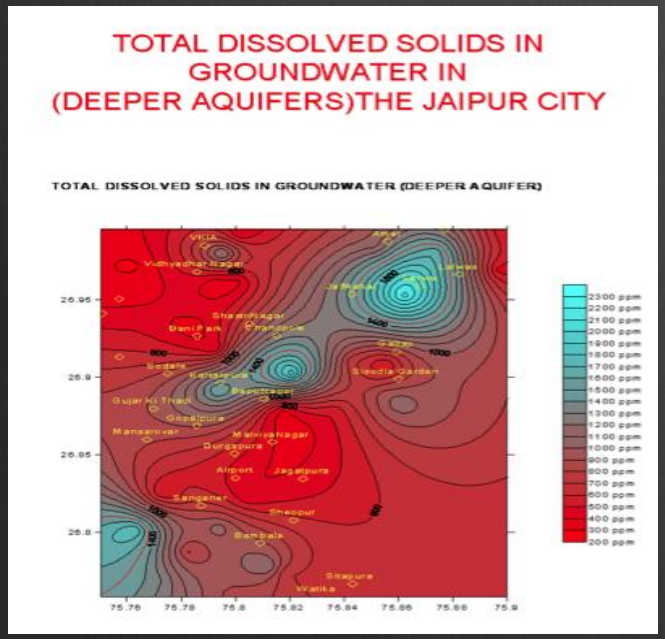
- Role of Government and Policy
  - Water Metering
    - According to the Public Health Engineering Department, there are 384,058 metered connections in the Jaipur water supply scheme.
    - However, about 60% of meters are not functional.
    - Lack of adequate replacements of water meters is attributed to a shortage of staff and a low meter repair rate.

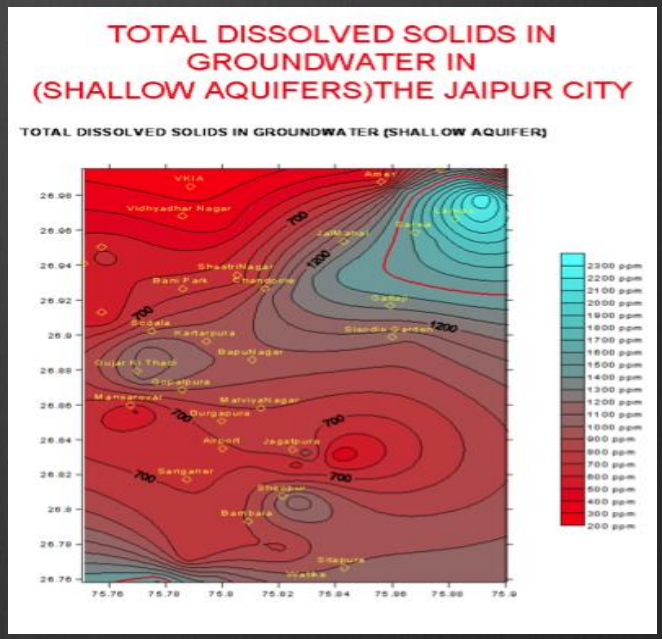
Current Supply Scheme & Management

- Estimates of Water Supply & Demand
  - Public Health Engineering Department
    - Water demand is 462 million liters per day (l/d), water supply from the government is 374 million l/d, and thus, ***there is a water supply deficit of 90 million l/d.***
    - Average water supply system production in 2010 of 401 million l/d. Of the 401 million l/d, 368.32 million l/d came from tube wells while 32.64 million l/d came from Bisalpur Dam.
  - It is difficult to make accurate estimates for water demand due to the presence of many tourists, large migration fluxes, high unaccounted for distribution losses, and inadequate water metering for customers.

Current Supply Scheme & Management

- Drinking Water Quality
  - Water Quality is a serious concern- specifically Total Dissolved Solids, Nitrate, and Fluoride.
    - Also: Bicarbonate, Potassium, Calcium, Magnesium, Metals (Manganese, Iron, Nickel, Lead, and Cadmium).

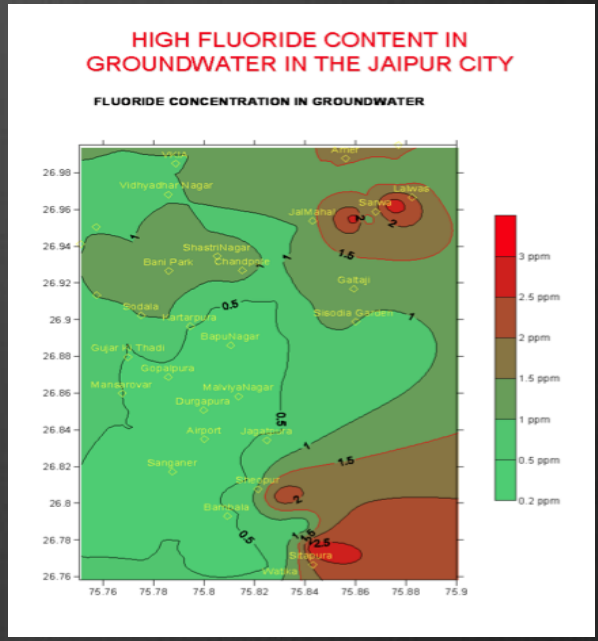


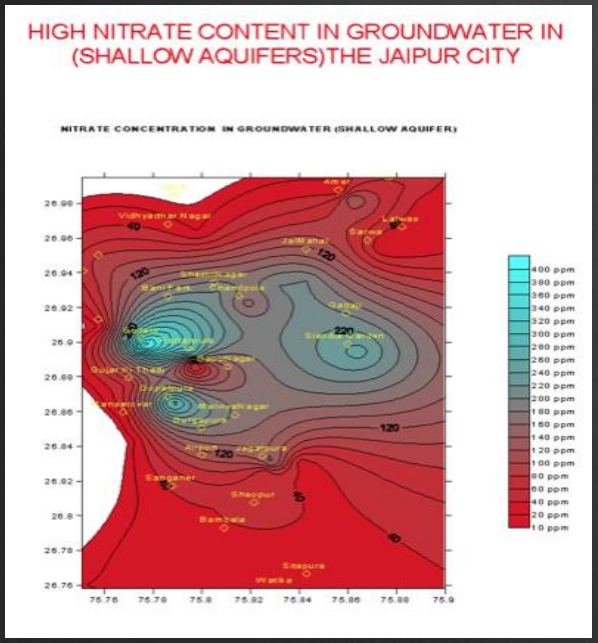


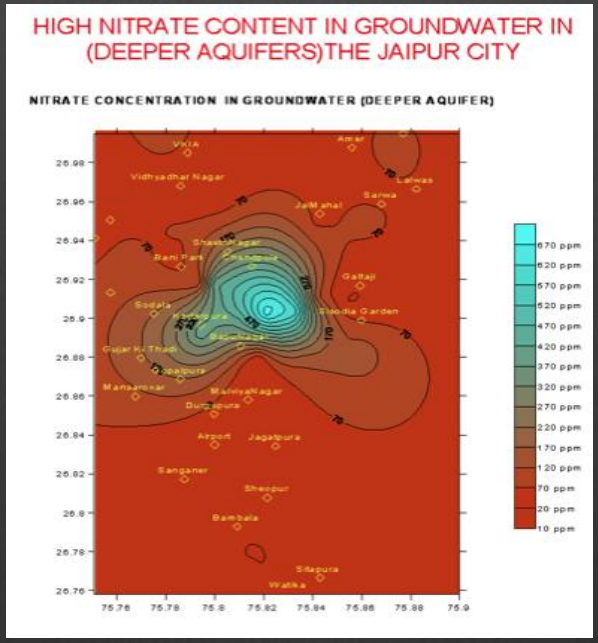
Source: 20

Current Supply Scheme & Management

- Nitrate & Fluoride levels in Jaipur's groundwater.







Current Supply Scheme & Management

- The Impact of Climate Change
  - No significant trends in annual rainfall or seasonal rainfall for 1901-2008.
  - The last twenty years or so have entered into a phase of downward trending rainfall and high variability.
  - Median annual rainfall is likely to decrease by 2040.
  - Rainfall is likely to decrease in all seasons except the post-monsoon season (but not likely to offset decreases in other seasons).
  - Climate change will likely continue the path of high variability, putting a strain on the water supply scheme.

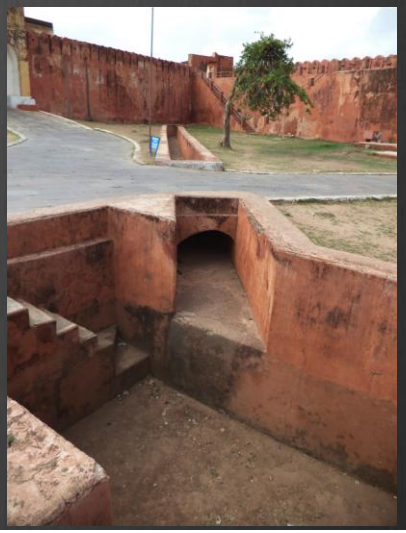
Future Water Supply Scheme

- An Emphasis on Traditional Water Systems
  - Traditional water systems were often kept small enough to be easily managed & controlled by pooling together the capital, labor, & technical system at community scale.
  - Economic independence & optimization of local resources operated at a micro-level - the community took care of catchment areas and social prohibitions often curbed grazing in certain seasons, using catchment areas for toilet purposes, and dumping of animal carcasses.
  - Traditional technologies and systems could not meet the water demands due to the growth in population.
    - The government has developed a bias for large complex and costly systems with low capital efficiency, fostering a greater dependence on the state for all matters such as maintenance of existing systems. This has decreased community participation in maintenance and care of their water system.

Future Water Supply Scheme

- An Emphasis on Traditional Water Systems
  - The modern systems that have replaced traditional systems depend on large-scale allocation of state funds and elaborate bureaucracy to manage them. These modern water technologies have mostly been imported from the West without regard to local conditions and features.
  - The forts built around Jaipur and its original layout exhibit traditional water harvesting techniques.
    - Jaigarh Fort has many wide water channels and three water tanks, with the largest tank having the capacity of storing 6,000,000 gallons of water. Water channels were built in the Aravalli catchment and conveyed water to Jaigarh Fort. Rainwater capture and storage systems are also present at Amer and Nahargarh Fort.

Traditional Water Systems at Jaipur Forts



Source: Personal Photographs

Future Water Supply Scheme: General Recommendations

1. **Increasing Open Areas**
   - As Jaipur has expanded, forestlands, agricultural fields, pasturelands, and open wasteland have decreased and paved area have increased.
     - These open areas are important for soaking up rainwater and recharging the aquifers.
     - The increase in impervious areas not only inhibits the percolation of rainwater to recharge the aquifers, it also creates flooding issues, as the water has nowhere to go but follow the surface slope of the land.

Recharge shafts/trenches could help alleviate these problems

Future Water Supply Scheme: General Recommendations

2. Conservation of Surface Water

- Those water ponds that have not come under the influence of urbanization and pollution must be kept as pristine as possible for the sake of a clean water source and recharge of the aquifers with clean water.
- Water ponds that have come under the influence of urbanization and pollution should be restored, as this pollution may infiltrate and degrade the quality of groundwater (which is near-impossible to fix once it has been degraded).
- Unaccounted for settlements, agriculture, and industry around surface water sources must be restricted as much as possible.
- Curtailment of construction that would cause diversions of water flow must be implemented so that these surface water sources have the opportunity to fill, as well as recharge groundwater sources.

Future Water Supply Scheme: General Recommendations

3. Fluoride Pollution

- Fluoride pollution may result from drawdown of the groundwater table thus magnifying natural fluoride levels from fluoride bearing minerals,but discharge of textile dying wastewaters also contributes to high fluoride content in waters.
  - ***Deflouridation treatment must be required for these industries, & low-cost domestic defluoridation technologies are available.***
  - ***It would be even more beneficial if high fluoride rich dyes were banned, & only the use of organic dyes were allowed.***

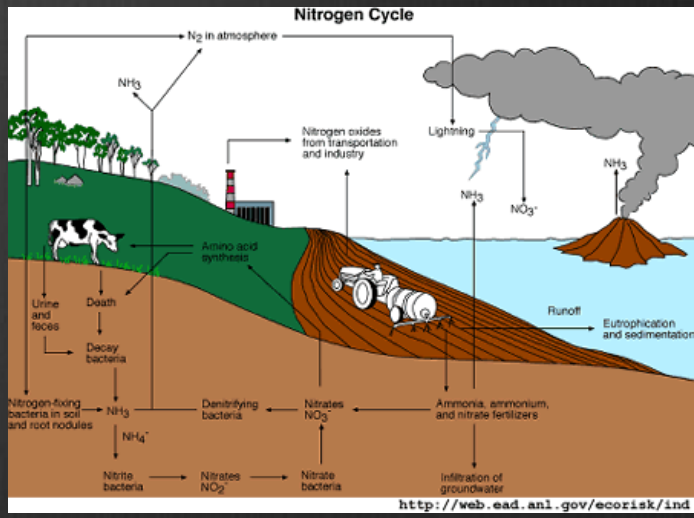
Future Water Supply Scheme: General Recommendations

4. Pollution Prevention & Minimizing the Use of Fresh Water in Industrial Areas
   - Regulations should be put in place that effectively ban the discharge of industrial wastes into water bodies and require treatment of these effluents before release into water bodies.
   - Arrangements should be made for effective collection of semi-solid and solid wastes from industries, as well as institutions such as area hospitals, so carcinogenic or infectious materials do not pollute water bodies or groundwater.
   - Water-intensive industries and activities must not be further permitted in areas deemed over-exploited for groundwater and incentives for the adoption of recycling and reuse of wastewaters should be put in place to minimize unnecessary use of fresh water sources.
   - The government must formulate a plan for the treatment of sewage and industrial wastewaters, and use this reclaimed water for activities that do not necessarily need potable water

Future Water Supply Scheme: General Recommendations

5. Curbing Nitrate Pollution

- Investment in sanitation and sewage disposal systems, especially in densely populated areas such as the walled-city, is the most appropriate and effective way to curb further nitrate pollution in these areas.
- ***A proper sewage disposal system must be employed and maintenance should be given a priority.***



Future Water Supply Scheme: General Recommendations

6. **Educating the Public**
   - Education and public awareness campaigns must be put in place to curb the pollution of water sources from domestic solid and sewage wastes and to promote the conservation of fresh water.
   - ***The public must be made aware of the severity of water scarcity in Jaipur, and techniques to conserve water must be communicated to the public.***
     - Possible strategies include incentives for installation of rainwater collection and storage technologies and the use of dual water supply systems (using water of inferior quality for purposes other than drinking).
     - Ways to save domestic water include using a container of water for shaving and teeth brushing instead of using flowing tap water, bathing using buckets instead of bathtubs or showers, and the use of a bucket for clothes washing instead of more water intensive techniques.

Future Water Supply Scheme: General Recommendations

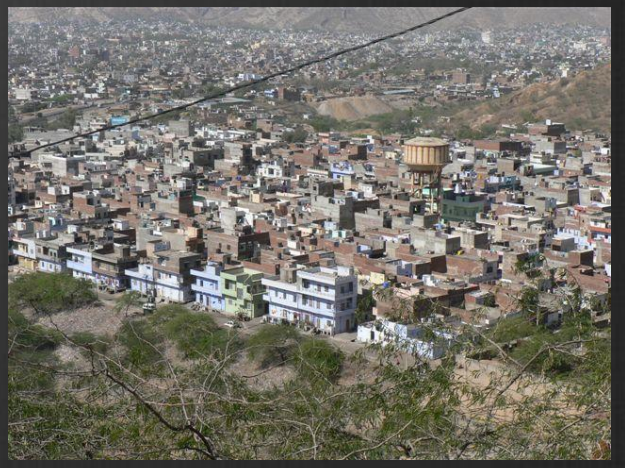
7. Groundwater Regulation & Conservation

- Permitting for further construction of groundwater extraction structures and registration of drilling agencies should be made mandatory and enforced to the greatest extent possible.
- Metering of new wells should occur, and groundwater should only be mined in proportion to open land area.
- It should be required that large-scale agricultural programs employ drip agricultural methods if they are to use groundwater sources.
- The government should invest in recharge shafts/trenches in order to allow for protection against flooding and recharge to aquifers.

Future Water Supply Scheme: General Recommendations

8. Development of Natural Resource & Land Use Monitoring System

- Unplanned expansion of the city and encroachments must be kept in check to alleviate problems to both the environment and people living in the area.
- ***Urban growth boundaries must be put in place so that further obstruction of natural water flow does not occur.***

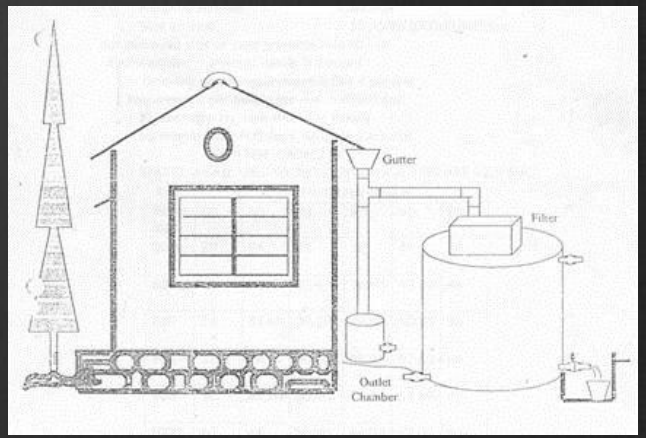


http://affordablehousinginstitute.org/blogs/us/2010/03/housing-options-in-india-part-3-market-housing.html

Future Water Supply Scheme: General Recommendations

9. Rooftop Rainwater Harvesting

- Recently rooftop rainwater harvesting has been made mandatory in state owned building of plot sizes more than 300 m^2 by the Central Ground Water Board of India.
- ***All newly constructed government buildings are to have rooftop rainwater harvesting structures.***
  - This must be strictly enforced and incentives created to encourage the construction of domestic rooftop rainwater harvesting structures.



http://theconstructor.org/water-resources/methods-of-rainwater-harvesting/5420/

Future Water Supply Scheme: General Recommendations

10. Investment in Update of Distribution Systems & Metering

- Current distribution losses in Jaipur's water system are estimated at about 40-50%; of this total water loss 80% is likely due to leaky service mains.
  - These losses result in both loss of revenue to the water department and low pressure for customers.
- Many meters are not functioning or not checked on a regular basis and the tariff system is undefined.
- ***A system must be put in place for regular meter checks so that billing can be done fairly and uniformly (i.e. customer does not get over- or under-billed), and to keep track of the status of these meters so they may be repaired if need be.***
- ***Investment should be made in installing and updating water metering systems.***

Future Water Supply Scheme: General Recommendations

11. Conservation of Water in the Irrigation Sector

- The government should initiate metering systems for agricultural wells so water charges for the intensive use of water can be levied.
- ***Incentives for growing low water requirement and salt tolerant crops in saline water areas and the installation of sprinkler and drip irrigation systems should both occur.***

12. Artificial Recharge from Paved Areas

- Paved areas inhibit recharge to groundwater; however, constructing recharge shafts/trenches, using pervious pavement, and improving existing storm water drain designs along roads, footpaths, etc. can initiate artificial recharge.

Policy Recommendations

- A shift in how the water supply sector is viewed must occur—the water supply and sanitation sector must be recognized as a utility service so that full cost recovery can be achieved.
- Adequate subsidies should be provided in a transparent manner to the poor in order to meet minimum water and sanitation requirements for all in Jaipur.
- Efforts must be made to achieve cost reduction in areas such as manpower, energy consumption, reduction in the waste of water, and improvements in billing and collecting.
- The government and water supply agencies must be invested in maintenance of the system on a continuous basis, with comprehensive metering as a necessary policy.

Policy Recommendations

- Greater inclusion of private companies in installation, operation, and management in the water supply and sanitation sector could also save the government money.
- The government and regional institutes could collaborate in order to provide training courses for those in or interested in the water supply and sanitation sector at different levels of education to both entice new workers in the field and ensure adequate educational preparedness.
- The government must pass and enforce legislation to curb overexploitation of groundwater, avoid deterioration of groundwater quality, and reduce the cost of pumping (incurred when pressures are low in the pumping system due to a lower water table).

Policy Recommendations

- The government must also put in place legislation or incentives to promote the reclamation and reuse of treated wastewater for uses such as horticulture, flushing sewers and toilets, air conditioning, cooling, and many other industrial uses in order to conserve fresh and potable water and reduce pollution load in the receiving water body.
- The government should have an open dialogue with leaders of various communities or interested community groups to determine necessary allocation of water sources for various activities.

Conclusions

- While Jaipur does only receive an average of 600 millimeters of precipitation per year, mostly in the monsoon months of June-September, we believe that ***Jaipur's water scarcity issues are mostly attributed to management issues***.
- Jaipur is considered one of the first planned cities of India, and when founded in 1727, adequate water supply for its citizens was a major concern.
- As Jaipur grew in population many measures had to be taken to maintain an adequate water supply.
  - The foundation for Jaipur's water scarcity issues today can be traced to a great population boom and rapid expansion of the city in the mid-1900s without adequate consideration of issues around the city layout and water supply.

Conclusions

- Calculations of water supply and demand consistently show a supply deficit.
- In addition to unreliable water sources for the future if the status quo continues, there are other problems compounding water issues in Jaipur:
  - Drinking water quality is poor in many areas of Jaipur.
  - Inadequate sewerage and waste disposal are having negative effects on water sources and the environment, in general.
  - The potential effects of climate change could also exacerbate all these problems.

Conclusions

- With investment by the government to change the system in place now, Jaipur could have a sustainable water future.
  - Measures such as increasing open areas, creation of artificial recharge zones, educating the public on water issues and conservation, reclamation and reuse of wastewater, rooftop rainwater harvesting, and investment in updating the water distribution and metering system will all help to improve the water supply system and Jaipur as a whole.
- ***Policy challenges must be overcome, but it is definitely possible to transform Jaipur from a city with extreme water scarcity issues to a city with a sustainable water supply for the future.***

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