Water Sensitive Urban Design and Planning (WSUDP): Mainstreaming urban water conservation

National seminar on
“Mainstreaming Sustainable Urban Water Management: Issue and challenges in policy and practice“
27 December, 2016
Shivali Jainer and Chhavi Sharda

Center for Science & Environment (CSE)
41- Tughlakabad Road, New Delhi
www.cseindia.org
Structure of Presentation

- **Overview of Urbanization In India:** Urban Development and Planning and water management

- **Case study of Dwarka sub-city**
  Some missed opportunities and potential of WSUDP.

- **In-situ water augmentation**
  Reuse of treated waste water- Missed opportunities in India

- **Best management practices at institutional scale**
  CSE and Delhi Jal Board (DJB)
1951 – 5 Indian cities greater then 1 million , 41 cities greater then 0.1 million population.

2011- 3 Indian cities greater then 10 million, 53 cities more than 1 million population.

377 million live in about 8000 urban centres.

Source: Aromar Revi
IIHS Publication (2012)
Spatial expansion has accelerated in top ten largest cities of India from 2000-10

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Master Plans</th>
<th>Land use Year</th>
<th>Population</th>
<th>Total (Ha)</th>
<th>Recreation/ Open space</th>
<th>Open space Sq.m/ capita</th>
<th>Percentage of open space</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Second Master Plan For Chennai Metropolitan Area only Chennai city</td>
<td>2006</td>
<td>4509210</td>
<td>17553</td>
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<td>3461</td>
<td>11.26</td>
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<td>4</td>
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<td>5</td>
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<td>2925</td>
<td>18.62</td>
<td>16.7 %</td>
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<tr>
<td>6</td>
<td>Draft Master Plan for portblair Planning Area</td>
<td>2001</td>
<td>99984</td>
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<td>101.25</td>
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<td>Master Plan for Lucknow</td>
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<td>2011</td>
<td>107676</td>
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<td>3000</td>
<td>278.61</td>
<td>22.1 %</td>
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<tr>
<td>9</td>
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<td>2010</td>
<td>72337</td>
<td>569</td>
<td>63.7</td>
<td>8.81</td>
<td>11.2 %</td>
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<tr>
<td>10</td>
<td>Master Plan Srinagar Metropolitan Area</td>
<td>2000</td>
<td>1200000</td>
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<td>481.31</td>
<td>4.01</td>
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<td>11</td>
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<td>1081622</td>
<td>21689.13</td>
<td>2602.686</td>
<td>24.06</td>
<td>12.0 %</td>
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<td>1524081</td>
<td>127122</td>
<td>300</td>
<td>1.97</td>
<td>0.2 %</td>
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<td>13</td>
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<td>2010</td>
<td>190418</td>
<td>1474.19</td>
<td>11.9</td>
<td>0.62</td>
<td>0.8 %</td>
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<tr>
<td>14</td>
<td>Noida Master Plan</td>
<td>2010</td>
<td>1068228</td>
<td>9210.74</td>
<td>1761.98</td>
<td>16.49</td>
<td>19.1 %</td>
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<td>15</td>
<td>Master Plan Amritsar</td>
<td>2010</td>
<td>1976050</td>
<td>139419.5</td>
<td>186.8</td>
<td>0.95</td>
<td>1.3 %</td>
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<tr>
<td>16</td>
<td>Bangalore Master Plan</td>
<td>2003</td>
<td>6501343</td>
<td>42141</td>
<td>1310</td>
<td>2.01</td>
<td>3.1 %</td>
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<tr>
<td>17</td>
<td>Mysore Nanjagund LPA-Mysore city</td>
<td>2009</td>
<td>7786510</td>
<td>27864.32</td>
<td>766.31</td>
<td>0.98</td>
<td>2.8 %</td>
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<tr>
<td>18</td>
<td>Master Plan Dehradun</td>
<td>2004</td>
<td>753420</td>
<td>9698.97</td>
<td>222.8</td>
<td>2.96</td>
<td>2.3 %</td>
</tr>
<tr>
<td>19</td>
<td>Master Plan for Kanpur City</td>
<td>2001</td>
<td>2551000</td>
<td>891311.66</td>
<td>958.08</td>
<td>3.76</td>
<td>1.1 %</td>
</tr>
<tr>
<td>20</td>
<td>Master plan Trivandrum</td>
<td>2012</td>
<td>989099</td>
<td>21586</td>
<td>54</td>
<td>0.55</td>
<td>0.3 %</td>
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<tr>
<td>21</td>
<td>Master Plan Airwal</td>
<td>2011</td>
<td>1054686</td>
<td>6648.231</td>
<td>1836.25</td>
<td>17.43</td>
<td>27.6 %</td>
</tr>
<tr>
<td>22</td>
<td>Chandigarh Master Plan</td>
<td>2011</td>
<td>1054686</td>
<td>6648.231</td>
<td>1836.25</td>
<td>17.43</td>
<td></td>
</tr>
</tbody>
</table>

Compiled from Master Plans of Indian cities

Landuse structure for urban centres

Metropolitan Cities & Megapolises

Small Towns

Medium towns

Large Cities

The residential cluster, which occupies the largest share of land use in city and towns, contains building rooftops, sidewalks, paved parking spaces, pervious areas that could be a garden or just open land and accessible roads.

Source: UDRPFI guidelines, 2014
Built up to open areas ratio:

**Pub. & Semi Public**
- Average built up area: 71%
- Open areas range: 29%

**Commercial**
- Average built up area: 70%
- Open areas range: 30%

**Residential**
- Average built up area: 71%
- Open areas range: 29%

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**Average built up to open areas ratio in urban areas**

- Average built up area: 76%
- Average open areas: 24%

The average Built up area range for a city/urban area is 21-26% while for open space, it is 74 - 79%. The standards and guidelines provide enough open area to design the SUDS structures.

Source: UDRPFI guidelines, 2014
Conventional break up of open areas for Dwarka, sector 23, Delhi

The conventional practice of making the surface paved, leads to loss of opportunity space for SUDS structure and also increase the runoff coefficient. However, the existing lawn/green space can be used to their full potential for designing and planning of SUDS structure.
Storm water and resource management - case study Dwarka

Urban Development: planned and executed in a manner so as to lower the hydrological impact of urbanization and present opportunities for improved water management.

RAINWATER: Availability in area, management to meet water demand in local areas.

WASTE WATER: managed and reused for non-domestic purposes

STORM WATER: managed through surface water bodies + optimal storm water channel: Green infrastructure

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Storm water and resource management - case study Dwarka
Table: calculation of discharge for each of catchment area of drain for 25 year peak hour rainfall.

<table>
<thead>
<tr>
<th>Trunk drains</th>
<th>Discharge Capacity</th>
<th>Area</th>
<th>Cumecs</th>
<th>(%) Increase in discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>TD5 18.26 Cusec</td>
<td>27</td>
<td>485</td>
<td>67.80</td>
<td>151.10</td>
</tr>
<tr>
<td>TD4 10.98 Cusec</td>
<td>14</td>
<td>324</td>
<td>48.58</td>
<td>247.03</td>
</tr>
</tbody>
</table>
Application of Sustainable strategy for Palam drain watershed area of Dwarka

Strategies for watershed area with case example of one of the watershed of drain TD-3 (Palam drain)

<table>
<thead>
<tr>
<th>RWHs in Catchment area for drain TD-3</th>
<th>Area (sqm)</th>
<th>Depth (m)</th>
<th>Volume (Cum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioretention</td>
<td>3299</td>
<td>0.3</td>
<td>989.7</td>
</tr>
<tr>
<td>pond 1</td>
<td>1507</td>
<td>0.3</td>
<td>452.1</td>
</tr>
<tr>
<td>pond 2</td>
<td>1569</td>
<td>0.3</td>
<td>470.7</td>
</tr>
<tr>
<td>swale</td>
<td>47690</td>
<td>0.1</td>
<td>4769</td>
</tr>
<tr>
<td>Retention basin 1</td>
<td>1247</td>
<td>0.3</td>
<td>374.1</td>
</tr>
<tr>
<td>retention basin 2</td>
<td>1839</td>
<td>0.3</td>
<td>551.7</td>
</tr>
<tr>
<td>gully trenches</td>
<td>75059</td>
<td>0.2</td>
<td>15011.8</td>
</tr>
<tr>
<td>total area</td>
<td>132210</td>
<td>total</td>
<td>22619.1</td>
</tr>
</tbody>
</table>

**Area-** 8% of public open space of watershed area

**Volume-** 20% of annual rainfall falling in the watershed (113095mm)

Thus 5% to 15% area of open space of each catchment area can retain 100% of 1 hour Peak Discharge from watershed for 25 year storm.
Bio-Retention area - Social space in dry periods.

Use of swale in sector level park

Bio retention areas in roundabouts

Site level - Integrated approach for SUDS+ rain water harvesting
For site with areas more than 1000 sq. m
Sites shall implement rain water harvesting:
Rain water falling on roof tops and other areas and where sufficient space is not available:
- Trench with Recharge Bore Well
- Recharge through existing dug Well
- Recharge through abandoned tube well, abandoned hand pumps
- Percolation tanks etc.

OR
- SUDS source control and infiltration instruments such as infiltration trenches, infiltration basins, green roofs, permeable paving, etc.
- Minimum 75% of the total open area is to be green area, soft landscape.

Potential green space for suds

<table>
<thead>
<tr>
<th>landuse-case example</th>
<th>total area (sqm)</th>
<th>built up %</th>
<th>open vegetative %</th>
<th>open paved %</th>
<th>open lawn area %</th>
<th>potential area for SUDS</th>
<th>Potential area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>institutional</td>
<td>15546.0</td>
<td>19.5</td>
<td>13.3</td>
<td>10.0</td>
<td>16.7</td>
<td>4658.0</td>
<td>30</td>
</tr>
<tr>
<td>group housing</td>
<td>9247.0</td>
<td>22.2</td>
<td>3.5</td>
<td>28.6</td>
<td>45.8</td>
<td>4551.0</td>
<td>49</td>
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<tr>
<td>DDA housing</td>
<td>28745.0</td>
<td>36.5</td>
<td>59.0</td>
<td>4.6</td>
<td>0.0</td>
<td>16952.0</td>
<td>59</td>
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<tr>
<td>Park sector level</td>
<td>19794.0</td>
<td>0.0</td>
<td>42.4</td>
<td>0.0</td>
<td>57.6</td>
<td>19794.0</td>
<td>100</td>
</tr>
<tr>
<td>commercial</td>
<td>8584.0</td>
<td>22.2</td>
<td>9.8</td>
<td>68.0</td>
<td>0.0</td>
<td>845.0</td>
<td>10</td>
</tr>
</tbody>
</table>

Open green space, Residential, Institutional:
**Potential area for regional flood water harnessing**

For using the total potential of low lying area of site:

- By Construction of No. Of ponds to increase the capacity (depth not more than 0.6 m).
- Construction of inflow and outflow gates with sluice water movement and collection
- The total water collection by direct precipitation and by no. Of ponds is 6 mcm.
- This 6 mcm of water shall be used for bulk uses of Dwarka.

Direct precipitation over depression: 1.4 Mcm  
(6437 mm x 150 Ha x .3 coef)  
Regional flood: 37 Mcm  
Evaporation loss = 30% = 1mcm  
Total water storage capacity : 6Mcm

Use of water:  
Horticulture  
Construction works

Overall Runoff coefficient reduction from 0.62 to 0.4

Potential area in site for flood water harnessing

Major conclusions (Specific to Dwarka):

If strategies for only reduction of overall runoff coefficient are applied than 22% of reduction in peak discharge achieved. And after that if retention strategies for effective drainage systems applied for 5-10 % of public open space than 100% of exceeding peak discharge is reduced.
In-situ water augmentation
Reuse of treated waste water-
Missed opportunities in India
In-situ water augmentation
Reuse of treated waste water-
Missed opportunities in India
In-situ water augmentation - Reuse of treated wastewater

- Public toilets
- Markets/Offices
- Hospitals
- Schools/colleges
- Residential areas
- Single house
Urban Wastewater Management:
How we conventionally plan our cities?
Current Scenario: Contaminated Water Bodies

**DELHI TO GET 100% SEWERAGE COVER**

- Delhi's sewerage master plan proposes for augmentation of sewer network to more areas.
- **50%** of Delhi is not connected to piped sewerage network.
- 154 villages have no access to sewerage.
- 1,535 regularized colonies have no sewer network.

**Delhi's waste water generation in MGD (million gallons per day)**

- 2011: 680 MGD
- 2021 Projected: 863 MGD
- 2031 Projected: 1,062 MGD

**Missing link with Reuse**

**Parameter** | **Toilet flushing** | **Fire protection** | **Vehicle Exterior washing** | **Non-contact impoundments** | **Landscaping, Horticulture & Agriculture**
--- | --- | --- | --- | --- | ---
1. Turbidity (NTU) | <2 | <2 | <2 | <2 | Horticulture, Golf course:
AA | < 2 | AA |
2. SS | nil | nil | nil | nil | Non edible crops:
raw | cooked
3. TDS | nil | nil | nil | nil | Crops which are eaten:
30 | nil | 30
4. pH | 6.5 to 8.3 | | | |
5. Temperature °C | | | | | Used water
6. Oil & Grease | | | | | Secondary
7. Minimum Residual Chlorine | | | | | Tertiary
8. Total Kjeldahl Nitrogen as N | | | | | Disinfection/AOP
9. BOD | | | | | To remove most particulate matter, nutrients, TDS and nematode eggs
10. COD | | | | | To inactivate pathogens, trace constituents and emerging contaminants

Decentralised wastewater treatment for local reuse

For setting up a DWWT system the following steps are followed:

1. Define the objective for setting up the DWWT clearly - Type of reuse

2. Relevant data collection Example: Population and water consumption pattern

3. Site Feasibility: Identification of a feasible site (Topography, climatic conditions etc.)

4. Deciding the level of treatment required

5. Designing an appropriate treatment system

Recommended norms of treated sewage quality for specified activities at point of use
Source: CPHEEO, Manual on Sewerage and Sewage, 2015

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Toilet flushing</th>
<th>Fire protection</th>
<th>Vehicle Exterior washing</th>
<th>Non-contact Impoundments</th>
<th>Landscaping, Horticulture &amp; Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity (NTU)</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>AA</td>
</tr>
<tr>
<td>SS</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
<td>AA</td>
</tr>
<tr>
<td>TDS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2100</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.5 to 8.3</td>
</tr>
<tr>
<td>Temperature °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ambient</td>
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<tr>
<td>Oil &amp; Grease</td>
<td>10</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
<td>10</td>
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<tr>
<td>Minimum Residual Chlorine</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
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<tr>
<td>Total Kjeldahl Nitrogen as N</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>BOD</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>COD</td>
<td>AA</td>
<td>AA</td>
<td>AA</td>
<td>AA</td>
<td>30</td>
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<tr>
<td>Dissolved Phosphorous as P</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Nitrate Nitrogen as N</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>10</td>
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<tr>
<td>Faecal Coliform in 100 ml</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>230</td>
</tr>
<tr>
<td>Helminthic Eggs / litre</td>
<td>AA</td>
<td>AA</td>
<td>AA</td>
<td>AA</td>
<td>AA</td>
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<tr>
<td>Colour</td>
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</tr>
<tr>
<td>Odour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Colourless</td>
</tr>
</tbody>
</table>

All units in mg/l unless specified; AA as arising when other parameters are satisfied; A tolerance of plus 5% is allowable when yearly average values are considered.
**DWWT – Institutional Building, CSE**

**Centre for Science and Environment**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Details</th>
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<tbody>
<tr>
<td><strong>Type of Building</strong></td>
<td>Office Building</td>
</tr>
<tr>
<td><strong>Source of Wastewater</strong></td>
<td>Kitchen and Toilets</td>
</tr>
<tr>
<td><strong>Capacity of the system</strong></td>
<td>8KLD (Approx 150 Users)</td>
</tr>
<tr>
<td><strong>Re-use</strong></td>
<td>For maintaining greenery</td>
</tr>
<tr>
<td><strong>Capital Cost (2005)</strong></td>
<td>Rs. 2,25,000/-</td>
</tr>
<tr>
<td><strong>O&amp;M Cost (per annum)</strong></td>
<td>Rs. 30,000/-</td>
</tr>
<tr>
<td><strong>Year of Implementation</strong></td>
<td>2005</td>
</tr>
</tbody>
</table>

**Benefit –**

Freshwater (groundwater and municipal supply) not used in low end usage.

Monthly saving – Rs. 400 municipal supply and Rs. 2,500 if recycled water is purchase from tankers.

Grey water from the canteen

Black water from the toilets, AAGC
Units - Decentralised Wastewater Treatment System at CSE Building

- Septic tank / Settler
- Anaerobic Baffled Reactor
- Anaerobic Filter
- Planted Gravel Filter
- Vortex

Ten chambers with two chambers of anaerobic filters
**DWWT and local reuse at CSE building**

- Grease Trap
- Settler
- Mixing Chamber
- Black water from AAGC
- ABR
- Planted Gravel Filter bed

**Retrofit** – utilizing existing open spaces
Oil Trap
(Preliminary Treatment)

- Oil Removal from the wastewater coming out from the canteen

Settler
(Primary Treatment)

- Suspended solid removal
- Two chambered

Anaerobic Baffled Reactor
(Secondary Treatment)

- Organic Degradation (BOD/ COD Removal)
- 10 chambered with anaerobic filters in 2 chambers
- Pebbles used as filter material

Planted Gravel Filter Bed
(Secondary and Tertiary Treatment)

- Organic Degradation, Nitrogen and phosphate removal
- Gradient of about 1% to facilitate gravity flow
- Media – River bed pebbles
- Plant species – Canna, Typha

Physical Appearance of Water samples after treatment from various modules
DWWT and local reuse at Delhi Jal Board’s Head Office

Excavation at the site

Construction at the site

Top soil leveling for landscaping

Site after landscaping today

Layout
Units
Decentralised Wastewater Treatment System at DJB’s Head Office

Six chambers with two chambers of anaerobic filters

Plant species – Canna indica (red yellow and orange flowers)
## DWWT and local reuse at DJB’s Head Office

### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.4</td>
<td>7.5</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>110</td>
<td>23</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>344</td>
<td>96</td>
</tr>
<tr>
<td>Total Suspended Solids (mg/L)</td>
<td>376</td>
<td>97</td>
</tr>
<tr>
<td>Ammonia (mg/L)</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Phosphate</td>
<td>Traces</td>
<td>Nil</td>
</tr>
<tr>
<td>Faecal Coliform (per 100ml)</td>
<td>3600</td>
<td>93</td>
</tr>
</tbody>
</table>

### Images
- Treated water
- Reuse of treated water
- Surrounding areas
Mainstreaming water conservation and efficiency

(adapted from: Water Sensitive Urban Design Principles and Inspiration for Sustainable Stormwater Management in the City of the Future, 2006)
For more information:
Case studies of Decentralised/ Sustainable Wastewater Treatment Technologies
Visit: cseindia.org/node/3798

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