Sustainable Urban Water Management – Challenges and Opportunities in mainstreaming Climate Adaptation

Improving Flood Resilience in Guayaquil

Deltaras, ESPOI, Rebel Group, Urbanisten, Municipality Guayaquil, Partners voor Water

Ad Jeuken

5 March 2021
Project location

Deltas
Goal

- Improve resilience to floods in the Delta city of the Guayaquil
- Implementation of innovative tools for urban development and flood management

Unique elements:
- Full scale CRIDA application
- Novel application to tidal and pluvial flooding
- Combining Climate with social and economic vulnerability
- Integration urban design & stakeholder perception

Deltabes
Storyline flood vulnerability analysis and strategic response (CRIDA approach)

Step 1) Decision context
• Problem analysis – problem tree and impact indicators
• Selection of performance metrics for stress test

Step 2) Vulnerability and impact analysis (Floods and Socio-economic)
• Selecting drivers and ranges for stress test
• Results of stress test and selecting a strategic approach
• Approach to socio-economic vulnerability and results
• Defining and selecting priority areas for interventions based on impact (combination of flood depth and socio-economic vulnerability)

Step 3) Identification and Selection of interventions
• Selection of interventions for priority areas
• Integrated design of three alternatives for priority areas

Step 4) Evaluation of plan alternatives
• With attention to ecosystem services of measure, and operational costs

Step 5) Implementation of selected interventions
• With attention to financing opportunities

Deltres
1) Decision context

- Stakeholder analysis
- Problem analysis – problem tree and impact indicators
- Selection of performance metrics for stress test
- Objectives and preferences
Consider three characteristic zones:
1 coastal, 2 commercial, 3 residential
Performance metrics

Are critical depths (0.2, 0.4) exceeded over significant large areas, for critical durations?

- Water depth on the streets
  *How deep is the flood?*

- Drainage time
  *How long will the flood last?*

- Flood extension
  *How large area is hit?*

Model output
Outliers

Based on water on streets
2) Stress Test – using modified decision scaling approach

- Event-based
- Plausible shifts based on climate projections and science
The system model SOBEK1D
drainage system model + 2D Dflow
Stress test input

- Rainfall intensity and duration and frequency
- Water level in the estuary depending on Tide, SLR and swelling effect el Nino. Note that el Nino and peak tide are recurring (4-5y, annually) and SLR is gradually increasing.
We show stress test plots:
- Flood depth (10 max)
- Area (ha) > 0.2 m (now missing)

And selected plots of flood area >0.2m against time (illustrating retention)
Zona 1 (rectangles showing shifts due to SLR (+0.3, +1m) and CC (+10%, +20%))
Zona 2

BAU(Z2): Profundidades de inundación, [m]

BAU(Z2-3hr): Profundidades de inundación, [m]

BAU(Z2-5hr): Profundidades de inundación, [m]

BAU(Z2-10hr): Profundidades de inundación, [m]

BAU(Z2-18hr): Profundidades de inundación, [m]

Max

10 Max
Zona 3

Max

10 Max
1/25 event now ~ 1/10 event 2050
4 scenarios are shown:
- TR100, 4m, 18hr, worst case;
- TR50, 3m, 18h, bad nino;
- TR25, 3m, 5h, future design;
- TR10, 2m, 5h, current design
Conclusions

• In general the critical water depths over 0.2 are occurring regularly (between 1/1 and 1/10 years), over 0.4 are occurring less regularly (~1/25y).

• Precipitation is the dominant driver in all three zones at regular tidal levels.

• With increasing sea levels zone 1 experiences most sea influence, turning into dominance from 3m (Coastal inundation)

• In a worse case situation, with prolonged precipitation over 18 hours and 4m sea level we can see a clear ‘accumulation’ of the flood because the drainage system cannot empty. Under more regular conditions flood durations is short.

• Climate change will need slightly higher design standards for whole system (not only drainage).
  >RT10 and >2m SL

• Drainage system has still a decent capacity to prevent high level and prolonged flooding ->so project hypothesis still holds

• **BUT** there is strong need for improved basic information on Drainage System layout and functioning (e.g. flood monitoring) and DEM. Continuous improvement of system model and understanding

Deltarces
Selection of 2D maps for impact analysis and design

- D1 Baseline
- B2 Interagua
- C2 Bad Nino
- D.3 Worst case + extreme SLR

<table>
<thead>
<tr>
<th>Sub-escenarios</th>
<th>Período de retorno [año], P [mm]</th>
<th>Duración de lluvia [horas]</th>
<th>Marea (nivel de agua) [msnm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1</td>
<td>1 año, 60.9mm</td>
<td>3.5</td>
<td>1.4</td>
</tr>
<tr>
<td>A.2</td>
<td>1 año, 60.9mm</td>
<td>3.5</td>
<td>2.0</td>
</tr>
<tr>
<td>A.3</td>
<td>1 año, 60.9mm</td>
<td>3.5</td>
<td>4.0</td>
</tr>
<tr>
<td>B.1</td>
<td>10 años, 108.5mm</td>
<td>5</td>
<td>1.4</td>
</tr>
<tr>
<td>B.2</td>
<td>10 años, 108.5mm</td>
<td>5</td>
<td>2.0</td>
</tr>
<tr>
<td>B.3</td>
<td>10 años, 108.5mm</td>
<td>5</td>
<td>4.0</td>
</tr>
<tr>
<td>C.1</td>
<td>50 años, 204.6mm</td>
<td>18</td>
<td>2.0</td>
</tr>
<tr>
<td>C.2</td>
<td>50 años, 204.6mm</td>
<td>18</td>
<td>3.0</td>
</tr>
<tr>
<td>C.3</td>
<td>50 años, 204.6mm</td>
<td>18</td>
<td>4.0</td>
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<tr>
<td>D.1</td>
<td>100 años, 237.7mm</td>
<td>18</td>
<td>1.4</td>
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<tr>
<td>D.2</td>
<td>100 años, 237.7mm</td>
<td>18</td>
<td>2.0</td>
</tr>
<tr>
<td>D.3</td>
<td>100 años, 237.7mm</td>
<td>18</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Physical, Economic and Social vulnerability based on questionnaires
Hot spot selection

Deltares
Step 2: The Bottom-Up Vulnerability Assessment

A function of Impact and Plausibility

Future Risk

Quadrant II
Formulate Robust Actions

Quadrant IV
Formulate Robust and Flexible Actions

Quadrant I
Follow Standard Planning and Design Guidance

Quadrant III
Formulate Flexible Actions

Based on the confidence in data and model

Green spatial measures

Improve drainage

Flood barriers

Zoning, retreat

SEA-LEVEL RISE
LOW TO MODERATE SEA-LEVEL RISE
HIGH-END SEA-LEVEL RISE
short term
medium term
long term
3) Formulate plan alternatives
Designing solutions for hot spots

BLUE GREEN EDGE PARK - rescuing the indigenous landscape and making places for the neighborhood
3 Alternatives for zone 3

**ESTRATEGIA 1**
CARRETERA PERMEABLE

**ESTRATEGIA 2**
LÍNEA VERDE

**ESTRATEGIA 3**
CALLE TRANSITABLE

*Rediseñar la calle manteniendo su actual sección funcional.*

*Rediseñar la calle reemplazando la berma con una continua y lujosa bioswale.*

*Rediseñar maximizando el espacio transitable e introducir verde en las rutas peatonales.*
Visión de conjunto: Capacidad de almacenaje potencial de agua - extrapolación a todas las calles comerciales principales

LONGITUD TOTAL DE LAS CALLES COMERCIALES PRINCIPALES

22.670m

Estrategia 1: CALLE PERMEABLE

Almacenaje de agua bajo la carretera
1.9 m³

Pavimento permeable + zona central
5 m³

Capacidad total de almacenaje de agua en todas las calles comerciales
43.070 m³

Superficie permeable total en todas las calles comerciales
113.350 m³

Estrategia 2: LÍNEA VERDE

Bioswale (linear)
1.775 m³

Pavimento permeable + Bioswale (linear)
5.35 m³

Capacidad total de almacenaje de agua en todas las calles comerciales
40.240 m³

Superficie permeable total en todas las calles comerciales
121.285 m³

Estrategia 3: CALLE TRANSITABLE

Bioswale (linear)
2.5 m³

Capacidad total de almacenaje de agua en todas las calles comerciales
56.675 m³

Superficie permeable total en todas las calles comerciales
113.350 m³
3 Alternatives for zone 2

**ESTRATEGIA 1**
**PERMEABLE**

Rediseñar la calle manteniendo su actual sección funcional.

**ESTRATEGIA 2**
**VERDE**

Rediseñar remplazando plazas de aparcamiento por bioswales.

**ESTRATEGIA 3**
**RECLAMO**

Rediseñar maximizando el verde y reclamando el espacio público para los peatones.
Step 4) Evaluation of plan alternatives: Effectiveness

<table>
<thead>
<tr>
<th>Zone</th>
<th>Strategy</th>
<th>Reduction of flood extension</th>
<th>Reduction of drainage time</th>
<th>Reduction of water depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Coastal zone</td>
<td>Unica</td>
<td>8%</td>
<td>40%</td>
<td>20%</td>
</tr>
<tr>
<td>2. Comercial</td>
<td>Strategy 1</td>
<td>68%</td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>Strategy 2</td>
<td>70%</td>
<td>0%</td>
<td>16%</td>
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<tr>
<td></td>
<td>Strategy 3</td>
<td>66%</td>
<td>71%</td>
<td>40%</td>
</tr>
<tr>
<td>3. Residencial</td>
<td>Strategy 1</td>
<td>24%</td>
<td>0%</td>
<td>11%</td>
</tr>
<tr>
<td></td>
<td>Strategy 2</td>
<td>35%</td>
<td>0%</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>Strategy 3</td>
<td>57%</td>
<td>90%</td>
<td>47%</td>
</tr>
</tbody>
</table>
Imagen 73. Comparación de área inundada y niveles de inundación para la Zona 2. Izquierda: BAU TR10; derecha: Solución B TR 10.

Imagen 74. Comparación de área inundada y niveles de inundación para la Zona 1. Izquierda: BAU TR10; solución de Zona 1 TR10, línea roja representa barrera vegetal.
## Costs and benefits

<table>
<thead>
<tr>
<th>Zona 1</th>
<th>Zona 2</th>
<th>Zona 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parque natural</td>
<td>Carretera permeable</td>
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<td></td>
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<td>*</td>
</tr>
<tr>
<td></td>
<td>Imago y identificación</td>
<td>*</td>
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<tr>
<td></td>
<td>Bienestar (mental, físico, social)</td>
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<tr>
<td></td>
<td>Seguridad</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Valor educacional</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Valor comercial</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Árboles</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Áreas bioswales</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Pavimento permeable</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Cooling (refrescar)</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Polinización y biodiversidad</td>
<td>**</td>
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<td></td>
<td>Capacidad de almacenamiento</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Agua limpia</td>
<td>**</td>
</tr>
</tbody>
</table>

### Low Intervention Strategy (1)
- n/a
- n/a
- ~34,000
- ~6,000
- ~407,000

### Average Intervention Strategy (2)
- n/a
- n/a
- ~85,000
- ~6,500
- ~419,000

### High Intervention Strategy (3)
- ~2,700,000
- ~33,000
- ~76,000
- ~7,500
- ~543,000
- ~21,000
Lessons learnt and way forward

• CRIDA has potential for urban application
• Need to include preferences from citizens and business at an early stage
• This also provides an opportunity for additional data collection
• Need to include all relevant departments for spatial planning, transport, parks, risk management etc.
• Green solutions proposed fit in an integrated view of solutions in space and time
• Analysis and monitoring should be well integrated in the urban WASH management
• Project provided a good basis for implementation
• And upscaling

Deltarés
Thanks for listening

Contact details:

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Links to shown software:

https://publicwiki.deltres.nl/display/AP/Adaptation+Pathways
