Shifting Mines: Countering "New" Legacy Contamination in Flooded Areas using 2D hydraulic models

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Mine Action in Israel 2012-2017

- Legislation in 2011. Civilian Authority clears the mine affected areas, sets priorities, standards etc.
- State budget at least 8 mil USD per year.
- 8 clearance operators, 4 QA operators.
- NTS made by INMAA. TS and Clearance by companies participating in tenders.
- Average land release per year 1.5 km². Over 150,000 items destroyed.
- AVG clearance cost is 9USD per m².
Along the Israeli borders, large areas of land have been designated as SHA’s as a result of the potential mobilization of Anti Personal Mines (PRBM-35 and No10 types) by major floods over the last 50 years.

The was a clear need of a scientific tool that will define better the different risk levels and allow partial area cancelation and reduction in the SHA.
The History of the SHA’s

SHA’s areas were defined and marked between 1968-2012 based on:

- Visual observation during the floods. All wet areas were included.
- Farmers that found “new” mines in their fields around the flooded areas and reported to the Military.
- General assumption that mines are situated all over the washed area – from bank to bank.
The concept

- The work included the construction methodology, to map the movement of mines by floods and to set up different levels of risk for SHA demining projects by reconstructed floods flow fields by advanced hydraulic models.
The Methodology

GIS Database – LIDAR – DEM of Past Floods

Rainfall Data → Physical Data of Catchment → Mines and Aux's Type → Hydrologic Analysis → Flood Hydrograph → 2D Hydraulic Analysis → Water Levels and Valosity Raster's in Flooded Areas → Final GIS Analysis → Final Risk Maps
The testing results

- Area of 1,230,000 m² was cleared, with 379 mines found. (mines out of their original position in the minefield)
- 97% of the mines were found in RED areas.
- 3% of the mines were found in YELLOW areas.
- NO MINES found in GREEN and BLUE areas – 30% of the total area.
Completed on 5 sites in Israel

- Tamar - Dead Sea
- Zin - Dead Sea
- Sapir - Arava
- Tzukim - Arava
- Naama - Jordan valley
Lab Work
Lab Test - Flow Experiment

<table>
<thead>
<tr>
<th>Grain Size</th>
<th>Axis</th>
<th>Count</th>
<th>Mean</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard Deviation</th>
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<tbody>
<tr>
<td>Medium</td>
<td>a(cm)</td>
<td>71</td>
<td>10.31</td>
<td>10</td>
<td>6</td>
<td>15</td>
<td>1.64</td>
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<tr>
<td></td>
<td>b(cm)</td>
<td>71</td>
<td>6.7</td>
<td>7</td>
<td>4</td>
<td>9</td>
<td>1.05</td>
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<tr>
<td>Pebble</td>
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<td>73</td>
<td>5.21</td>
<td>5</td>
<td>2</td>
<td>9</td>
<td>1.76</td>
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<tr>
<td></td>
<td>b(cm)</td>
<td>73</td>
<td>3.38</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>1.24</td>
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<tr>
<td>Small Pebble</td>
<td>a(cm)</td>
<td>70</td>
<td>2.89</td>
<td>2.9</td>
<td>2.1</td>
<td>3.5</td>
<td>0.32</td>
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<tr>
<td></td>
<td>b(cm)</td>
<td>70</td>
<td>1.96</td>
<td>2</td>
<td>1.4</td>
<td>2.5</td>
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<tr>
<td>Gravel</td>
<td>a(cm)</td>
<td>72</td>
<td>0.97</td>
<td>0.9</td>
<td>0.5</td>
<td>2</td>
<td>0.28</td>
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<tr>
<td></td>
<td>b(cm)</td>
<td>72</td>
<td>0.63</td>
<td>0.6</td>
<td>0.4</td>
<td>1.1</td>
<td>0.15</td>
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</tbody>
</table>

Small Gravel

Gravel

Small Pebble

Medium Pebble
Lab Test - Flow Experiment
Lab Test- Flow Experiment

Summary Statistics

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
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<tbody>
<tr>
<td>Mean</td>
<td>0.6589551</td>
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<td>Std Dev</td>
<td>0.1690146</td>
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<tr>
<td>Std Err Mean</td>
<td>0.0018964</td>
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<tr>
<td>Upper 95% Mean</td>
<td>0.6626725</td>
</tr>
<tr>
<td>Lower 95% Mean</td>
<td>0.6552376</td>
</tr>
<tr>
<td>N</td>
<td>7943</td>
</tr>
</tbody>
</table>
Lab Test- Flow Experiment

Flow at SHA areas

- Yes
  - Hydraulic Condition (V < 0.3 m/sec or D < 0.1 m or VD < 0.03 m^2/sec)
    - Yes: Medium Risk
    - No: High Risk
- No: Very Low Risk

Hydraulic Connection to the Mine Field

- Yes
  - Medium Risk
- No
  - Low Risk
- Solves mass and momentum
- Can be quick to set up
- Do not have to define flow paths
- Obtain depths and velocities in 2D
- A typical model grid is for 4-25 km^2 corresponding to 160,000-1,000,000 cells.
- Run time 4-24 hours
- Now more achievable due to
  - Data sets/coverage
  - Computing power (speed)
  - Distributed processing
Tzukim Site

Hazardous Suspected Area

EGYPT

ISRAEL

JORDAN

EGYPT

ISRAEL

JORDAN
2D Hydraulic simulation
Tzukim Site 2010 Flood Event
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Sapir site

Mining suspected areas

Hydraulic model
2D Hydraulic simulation
Sapir Site 2010 Event

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Maps of mine found in Sapir site over flow field

V(m/sec)

- 2010
- 1970
Flow velocity map Sapir Site 2010

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Risk zone map Sapir Site 2010
### Mines vs. Vegetation

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>No. Mines</th>
<th>% from total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>77</td>
<td>19.44</td>
</tr>
<tr>
<td>5-10</td>
<td>123</td>
<td>31.06</td>
</tr>
<tr>
<td>10-15</td>
<td>87</td>
<td>21.97</td>
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<tr>
<td>&gt;15</td>
<td>109</td>
<td>27.53</td>
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<tr>
<td>Total</td>
<td>396</td>
<td>100</td>
</tr>
</tbody>
</table>
Using the tool 2014-2017

- The tool is currently in use. Was activated in 5 areas.
- In these 5 areas 11,985,000 m² were cancelled.
- Saved INMAA over 100,000,000 USD until now.
Summary and Conclusion

1. New methodology to reduce the size of the Suspected Hazardous Areas (SHA’s) using hydrological and 2D hydraulic modeling was newly developed.

2. The model was tested in 5 sites in Israel. The total low risk area is around 12,000,000 m² (51.3 % from total SHA area).

3. Ninety-seven percent (97%) of the 379 mines that were found at Sapir site were located in areas calculated to have a risk Category of 4 (high). The other 3% of the mines were found to be located in risk Category 3 (medium) areas. No mines were found in risk Category 1 (very low) areas or risk Category 2 (low) areas.

4. This methodology proved to reduce the work and risk associated with mine removal operations, save valuable resources, improve safety, and significantly cut costs (over 100 million US$) in IMMAA projects.