The Mechanics Rip Currents in the Great Lakes

G. Meadows, H. Purcell and L. Meadows

University of Michigan
Over 80% of all surf related rescues are attributable to Rip Currents.

According to the U.S. Lifesaving Association, in 1999 there were over 23,000 rip related rescues along U.S. beaches.

It is estimated that each year nearly 100 people drown from rip currents.

12 deaths in Michigan in 2003.

http://www.carefulparents.com/rip-currents.htm
SLEEPING BEAR DUNES
NATIONAL LAKE SHORE

Number one Midwest nature escape for families!
– Disney’s Family Fun

VISIT THIS SUMMER!
See special offers on other side

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COMPONENTS OF A RIP

• Neck
  – Strongest current

• Head
  – Current disperses beyond the breaker line

• Longshore Current or Feeder
  – Feeds the rip

• Breaker Zone
  – Slow onshore movement between rips

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RIP CURRENTS

- Swift, narrow currents that carry water, sand and debris off shore
- As long as 1 kilometer,
- Ranging from less than 10 to over 30 m in width
- With maximum velocities over 2 m/s
- Strongest outward moving current occurs where the wave height is lowest attracting unwary bathers to the more tranquil looking area of the beach.
**SEA VS. SWELL**

**Sea**
- Waves in the process of generation by the wind
- Sharp angular crests

**Swell**
- Waves that have traveled out of generation area
- Flatter crests
- Longer period

*Pinet, 2003*
Mechanics of Rip Current Generation

- Variable Longshore Bathymetry
- Variations in Longshore Wave Height
  - Intersecting Wave Trains
  - Edge Waves
- Coastal Structures
• Bigger waves induce larger currents
• Smaller waves create weaker, more numerous rip currents
• Well organized waves induce more organized currents
• Increased velocities (waves and currents) move more sand
  • Bigger bars
  • Bigger channels

IN ALL CASES
RIP CURRENTS EVOLVE IN BOTH SPACE AND TIME

- Once formed
  - Rips should be expected to persist and occupy existing channels

- After major storms
  - Existing bathymetry can be “erased’ and rips begin to create new channels

WHAT IS KNOWN

- Rip currents caused by a longshore variation in the build up of water in the surf zone
  - Topographic Refraction
  - Wave-Wave Interactions
  - Coastal Structures
- Rips increase with:
  - Increasing onshore wind
  - Decreasing water level (tides /seiches)
- Rips evolve in both space and time
- Swell-mechanisms well-understood
WHAT IS NOT WELL-UNDERSTOOD

- Locally Generated Sea Mechanisms
  - Great Lakes Storms
  - East Coast Nor-Easters
- Detailed Effects of Engineering Structures
- How to Make Detailed Site Predictions
- Seiches or Great Lakes wind tides
  - Contributes additional water to nearshore zone

- Changing Water Levels
  - Effects on nearshore slope
    - Low water results in steeper nearshore slopes
  - Effects on nearshore sand supply

- Climatological Cycles (Meadows et al., 2000)
  - Stronger winds lead increased water levels by 18 months
  - Sets stage for increased rip current frequency
THE GREAT LAKES BASIN

- Length Scale
  500 km

- Water Depths To
  400 meters

- Total Shoreline
  17,000 kilometers
GREAT LAKES SEAS

- Primarily Locally Generated
- Some Long Period Swell at the Ends of the Lakes
- Basins are Enclosed
• Seiches and Kelvin Waves
  • Contribute additional water to nearshore zone
• Strong Air/Sea Temperature Differences
  • Drive large and rapid wave growth
• Changing Water Levels
  • Effects on nearshore bathymetry and sediment supply
• Climatological Cycles (Meadows et al., 2000)
  • Stronger winds lead increased water levels by 18 months
  • Sets stage for increased rip current frequency on low water levels.
SEICHHING

WIND

STILL WATER LEVEL

HIGH LEVEL CAUSED BY WIND SET-UP

SET-DOWN

SET-UP

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AIR/SEA TEMPERATURE DIFFERENCES

Lake Michigan Average GLSEA Surface Water Temperature

(http://coastwatch.glerl.noaa.gov)

- 1999
- 2000
- 2001
- 2002
- 2003
- 2004

Surface Water Temperature (degrees C)

Fri Mar 26 06:40:01 2004
(from Great Lakes Surface Environmental Analysis)

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Edmund Fitzgerald
November 10, 1975
29 of 29 lost

Carl D. Bradley
November 18, 1958
31 of 33 lost

The Great Storm of 1913
November 7-11
251 lost from 12 ships in 3 lakes
WATER LEVELS VARY ON MANY SCALES

- Long term, water levels recorded from 1860 to present
- Decadal Changes
- Seasonal Changes
- Daily Variations

Eagle Harbor in Ephraim, WI 10-25-99

http://www.glerl.noaa.gov/seagrant/glwlphotos/Michigan/LakeMichiganLevels.html#High
GREAT LAKES WATER LEVELS

Lake Michigan-Huron Hydrograph (1918-Present)

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WATER LEVELS EFFECT BEACH PROFILE

Case I: $\Delta L \leq Y_m$
\[ R = \frac{\Delta L}{\text{slope}} \]

Case II: $\Delta L > Y_m$
Volume Conservation, Volume Eroded = Volume Deposited
\[
(3/5) A (W-\Delta)^{5/3} - (3/5) A (W-R-\Delta)^{5/3} + (R\Delta L/2) - \Delta LW = 0
\]
Shoreline Advance = $X_m + R$
MULTIPLE STRAIGHT BARS

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RIP CHANNELS

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• Time Dependent Fluctuations in Longshore Currents, Meadows, 1976
• Unsteadiness in Longshore Currents, Wood and Meadows, 1975
EXISTING PREDICTIVE CAPABILITIES

- Waves
  - Well-predicted in Great Lakes
  - In Both Space and Time
- Flow Magnitudes - Offshore
  - Predictable to first order, Princeton Ocean Model
- Water Level Variations
  - Seasonal, Annual and Decadal
  - Short Term (Princeton Ocean Model)
### East Central Florida LURCS Checklist

<table>
<thead>
<tr>
<th>WIND FACTORS</th>
<th>MOST FAVORABLE FOR</th>
<th>MOST FAVORABLE FOR</th>
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<tbody>
<tr>
<td>SPEED / DIRECTION</td>
<td>RIP CURRENTS (40-110°)</td>
<td>LONGSHORE CURRENTS (120-160°, 340-30°)</td>
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<tr>
<td>5 kt</td>
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<td>0.0</td>
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<tr>
<td>5-10</td>
<td>1.0</td>
<td>0.5</td>
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<td>3.0</td>
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<tr>
<td>15-20</td>
<td>4.0</td>
<td>3.0</td>
</tr>
<tr>
<td>20</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>20-25</td>
<td>+5.0</td>
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<th>SWELL HEIGHT FACTOR</th>
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<tr>
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<tr>
<td>5-7</td>
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</tr>
<tr>
<td>8-10</td>
<td>4.0</td>
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<th>SWELL PERIOD FACTOR</th>
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<tr>
<td>7-8 sec</td>
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</tr>
<tr>
<td>9-10</td>
<td>1.0</td>
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<tr>
<td>11-12</td>
<td>2.0</td>
</tr>
<tr>
<td>&gt;12</td>
<td>3.0</td>
</tr>
</tbody>
</table>

### MISCELLANEOUS FACTORS

If astronomical tides are higher than normal (i.e., near full moon), add 0.5
If previous day Wind Factor or Swell Factor greater than or equal to 2.0/1.5, respectively, add 0.5

**If RIP CURRENT THREAT** is 3.0 - 4.0** (2.5 - 3.5 ** on weekends/major Holidays) issue statement for greater than normal threat of rip currents.

**If RIP CURRENT THREAT** is 4.5 - >5.0** (4.0 - >5.0 ** on weekends/major Holidays) issue statement for much greater than normal threat of rip currents and/or heavy surf.

Lascody, 1998
GREAT LAKES “TIDES”

- STILL WATER LEVEL
- HIGH LEVEL CAUSED BY WIND SET-UP

Kelvin wave crest
Motion of Kelvin wave crest
Amphidromic point

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THE NEXT STEP

- **Research**
  - Unique Great Lakes Nearshore Dynamics

- **Education**
  - Public Perception of Risk
  - Conditions and Signs

- **Outreach**
  - Coordinated with Sea Grant Extension

- **Technology Transfer**
  - Development of Accurate and Reliable Forecasting Tools

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S- Band Radar System

- Rip currents are difficult to capture with in situ current meters due to their episodic nature.
- S-Band radar is ideal for observing temporal and spatial variations in the rip current system.
- S-Band Radar is now available for MHL use.
Rip Currents are difficult to capture with in situ current meters due to their episodic nature.

S-Band radar is ideal for observing temporal and spatial variations in the rip current system.

Mobile X-band Radar
  - Sum Imagery to Record Bathymetry
  - 3D FFT Analysis for Currents, Wave Spectra

Transportable to Remote Sites

Provides Immediate Data Collection Response
Color scheme overlay on 3D mapped based on height-intensity of radar echo courtesy of Dr. Dennis Trizna