Mapping
Stormwater Outfalls
Paul Jordan
RI DEM
“…Outfall locations must be determined using Global Positioning System (GPS) units, … to generate latitude-longitude coordinates of sufficient accuracy to allow for the identification of individual pipes when revisiting their locations.”
<table>
<thead>
<tr>
<th>Inspector(s)</th>
<th>Flow Type</th>
<th>Outfall ID</th>
<th>Time</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Method of Collection</th>
<th>Accuracy in meters</th>
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</thead>
<tbody>
<tr>
<td>PJ</td>
<td>MODERATE</td>
<td>SC-01</td>
<td>6/12/2006 13:07</td>
<td>-71.467167</td>
<td>41.305167</td>
<td>GPS_CODE_(PSEUDO_RANGE)<em>STANDARD_POSITION</em>(SA_OFF)</td>
<td>&lt;15m</td>
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<td>If Other</td>
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<td>Narragansett Bay</td>
<td>CONCRETE</td>
<td></td>
<td>CIRCULAR</td>
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<td>12&quot;-35&quot;</td>
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</table>
GPS 101
Speed of Light Measurement

1. travel time of GPS signal from Satellite to Receiver

2. multiply elapsed time by 186,000 miles/sec
   
   time (sec) x 186,000 = distance
- Each satellite transmits a different code
- The receiver generates matching codes at the exact same time
- Then, receiver looks at the incoming code from the satellite and determines how long ago the receiver generated that code
Trilateration

One measurement narrows down our position to the surface of a sphere.

We are somewhere on the surface of this sphere.

11,000 miles
Trilateration

Second measurement narrows it down to the intersection of two spheres.

Intersection of two spheres is a circle.
Trilateration

Third measurement narrows to just two points.

Intersection of three spheres is only two points.
Trilateration

Fourth measurement will decide between the two points.

14,000 miles
11,000 miles
13,000 miles
12,000 miles
Factors Affecting GPS Accuracy

- Satellite Constellation Geometry
- Atmospheric Interference
- Timing Errors
- Signal Multi-Path
- Signal Strength
- RF Interference
Geometric Dilution of Precision (GDOP)

Relative position of satellites can affect error

Idealized situation
Trilateration

One measurement narrows down our position to the surface of a sphere.

We are 11,000 miles somewhere on the surface of this sphere.

Trimble Navigation
Geometric Dilution of Precision (GDOP)

Real situation - fuzzy circles

Point representing position is really a box

Trimble Navigation
Box gets bigger if satellites are closer together

Even worse at some angles
Geometric Dilution of Precision (GDOP)
Atmospheric Delays

- Ionosphere  (band of charged particles)
- Troposphere  (our weather)
Multipath Error
Differential GPS

- Uses 2 GPS receivers – one at a precisely known location (base station) and one as a rover

- Offset differences computed by the base station are used to correct the rover receiver’s positions

- Corrections can be applied in:
  - post processing routine
  - real-time beacon
Real-Time Differential GPS

Reference Station at a Known Location

RTCM Corrections
Accuracy Definitions

CEP
50%
7.5 m

RMS
68%
the square root of the average of the squared errors along the x & y axes
10 m

2D RMS
95%
15 m
(CEP) in Meters:
50% = 3.92
90% = 8.86
95% = 10.26
98% = 12.65
GPS Receiver Types

Consumer: $49 to $500
Mapping: $1,500 to $10,000
High Precision: to $40,000
On-Screen Page and Option Menu Buttons

Status Window

Ready To Navigate
Accuracy: 10 Feet

Inner Ring (Satellites within 45° angle from vertical)

Outer Ring (Satellites on the horizon)

Center (Satellite overhead)

Signal Strength bars

Satellite Page with 10 Satellites Being Tracked and WAAS Enabled.
WAAS Satellite is No. 35 and 'D' in Signal Bars

Location N 38°51.338' W094°47.930'
Elevation 1098'
Using the keyboard to edit
Live Demo

Linking Pictures with GPS Data:
Canon Digital Camera
Garmin eTtrex
Robogeo Software
QUESTIONS?

Links:

Garmin
http://www.garmin.com

Magellan
http://www.magellangps.com

Robogeo
http://www.robogeo.com/home

GPS Photolink
http://www.geospatialexperts.com

DNR Garmin
http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html