



NEW JERSEY AMERICAN WATER

NJAW GCIP

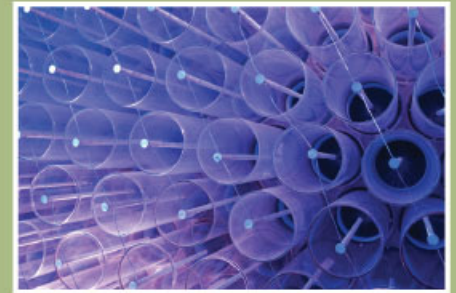
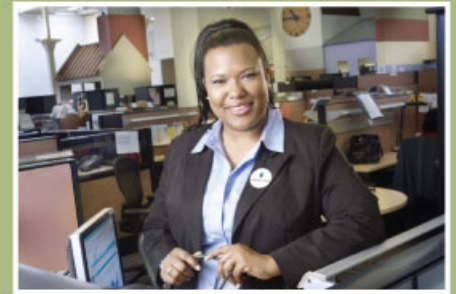
Geospatial Capital Investment Planning Toolset

Water Main Segment
Weighted Overlay Analysis

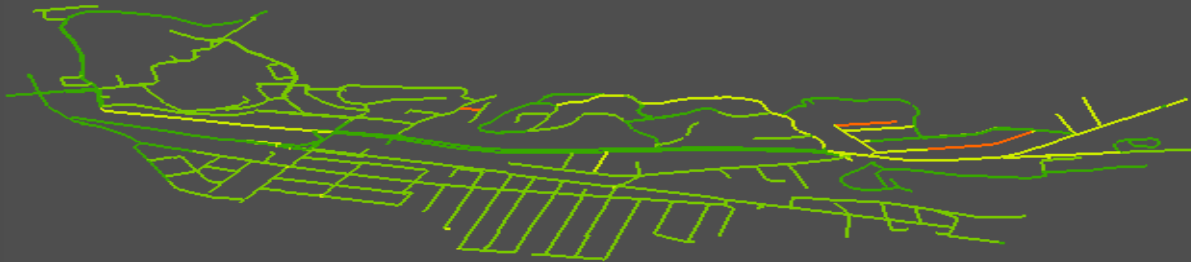
email: christopher.kahn@amwater.com

URL: www.amwater.com/njaw/

Christopher Kahn MGIS, GISP
Project Manager, GIS



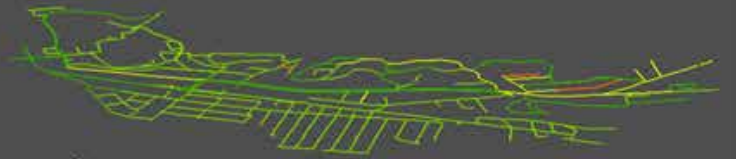
Aging Infrastructure



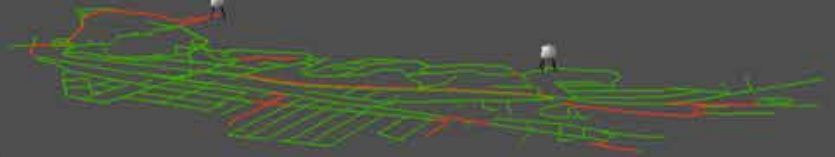
Where to Invest \$\$

- Many variables can influence water main deterioration
 - * GIS analysis limited to variables with data availability
 - * GIS models grade segments based on each variable
- Each segment's variable grades are weighted
- Overlay analysis produces a single comprehensive grade

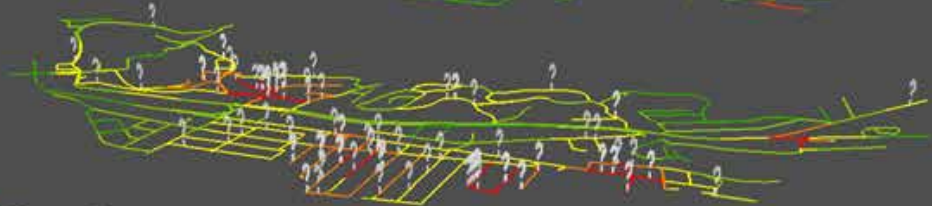
Aging Infrastructure



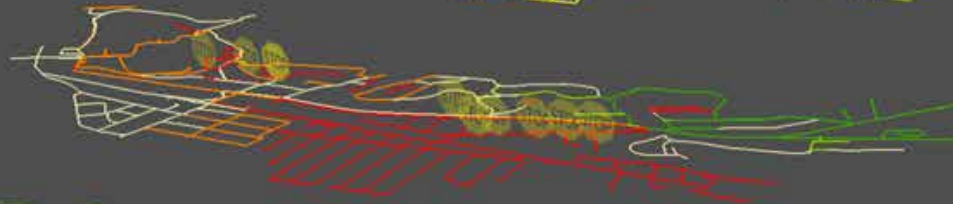
Critical Infrastructure



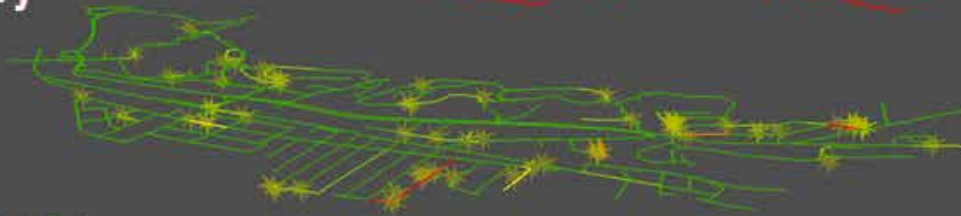
Quality Complaints



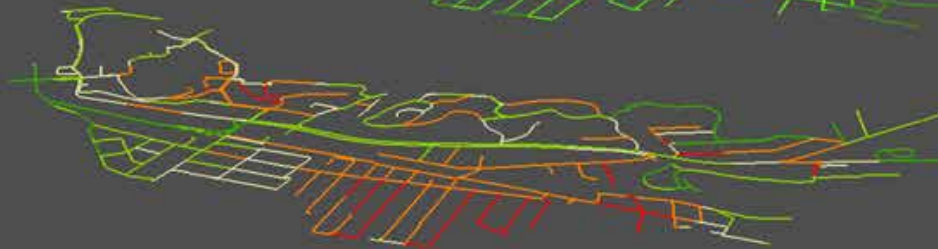
Fire Capacity



Repair History



Critical Points



Weighted Overlay

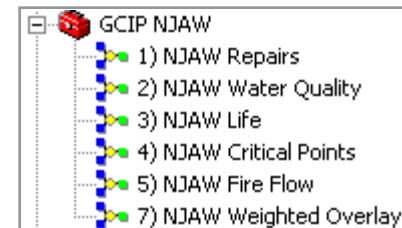


Geospatial Capital Investment Toolset (GCIP)

Targets only applicable variables with sufficient data to support analysis

- (1) Repair Model
- (2) Water Quality Model
- (3) Life Model
- (4) Critical Points Model
- (5) Fire Flow Model
- (6) Hydraulic Layer
 - § Pipe Criticality
 - § Pipe Fire Flow Capacity
- (7) Weighted Overlay Model

GCIP Toolbox





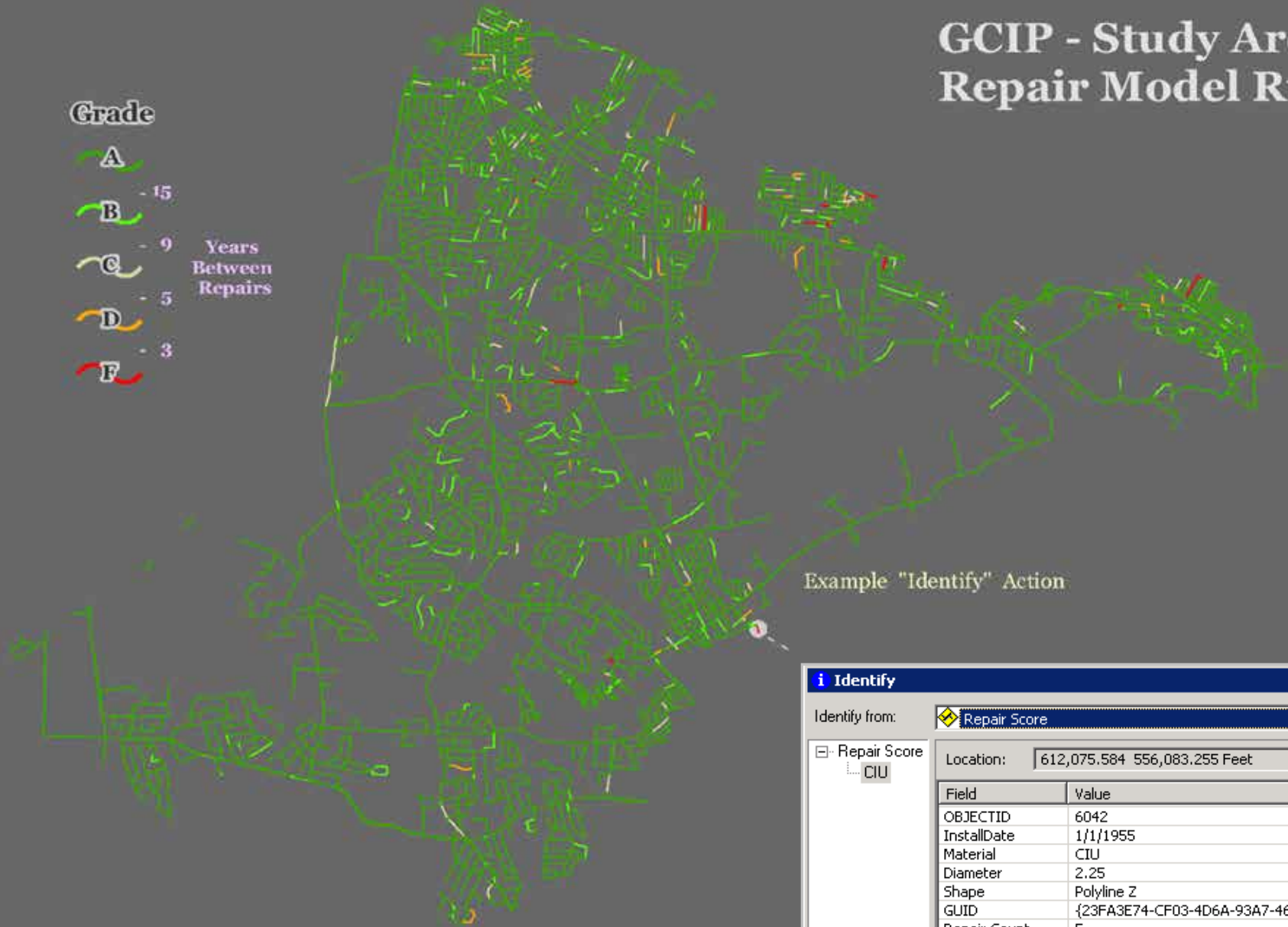
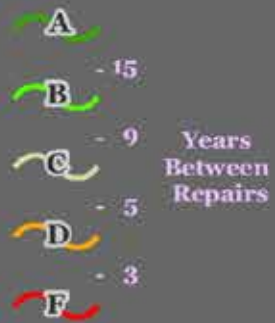
Repair Model

- **Measures:**
 - § The repair rate for each main segment.
- **Reason:**
 - § Past breaks are often a predictor of future breaks.
- **Input / Output:**

<i>o = optional</i> <i>Date = Date of Occurrence (or)</i> <i>Date of Install</i>	Attribute Fields								
	Date	Diameter	Material	GUID	Repair Count	Repair Rate	GCIP Rate	Score	Run Date
Inputs									
Geocoded Repair Points	✓	o	o	-	-	-	-	-	-
Water Mains	✓	✓	✓	✓	-	-	-	-	-
Output									
Repair Score Layer	✓	✓	✓	✓	✓	✓	✓	✓	✓

GCIP - Study Area Repair Model Run

Grade



Example "Identify" Action

Identify [?] [X]

Identify from: **Repair Score**

Repair Score
CIU

Location: 612,075.584 556,083.255 Feet

Field	Value
OBJECTID	6042
InstallDate	1/1/1955
Material	CIU
Diameter	2.25
Shape	Polyline Z
GUID	{23FA3E74-CF03-4D6A-93A7-464CBBDD34FF9}
Repair Count	5
Repair Rate (m/y)	6.19
Repair Rate (yrs)	3
Repair Score	5
Repair Run Date	6/27/2011 10:50:26 AM
Shape_Length	284.533534

7436 Total Main Segments

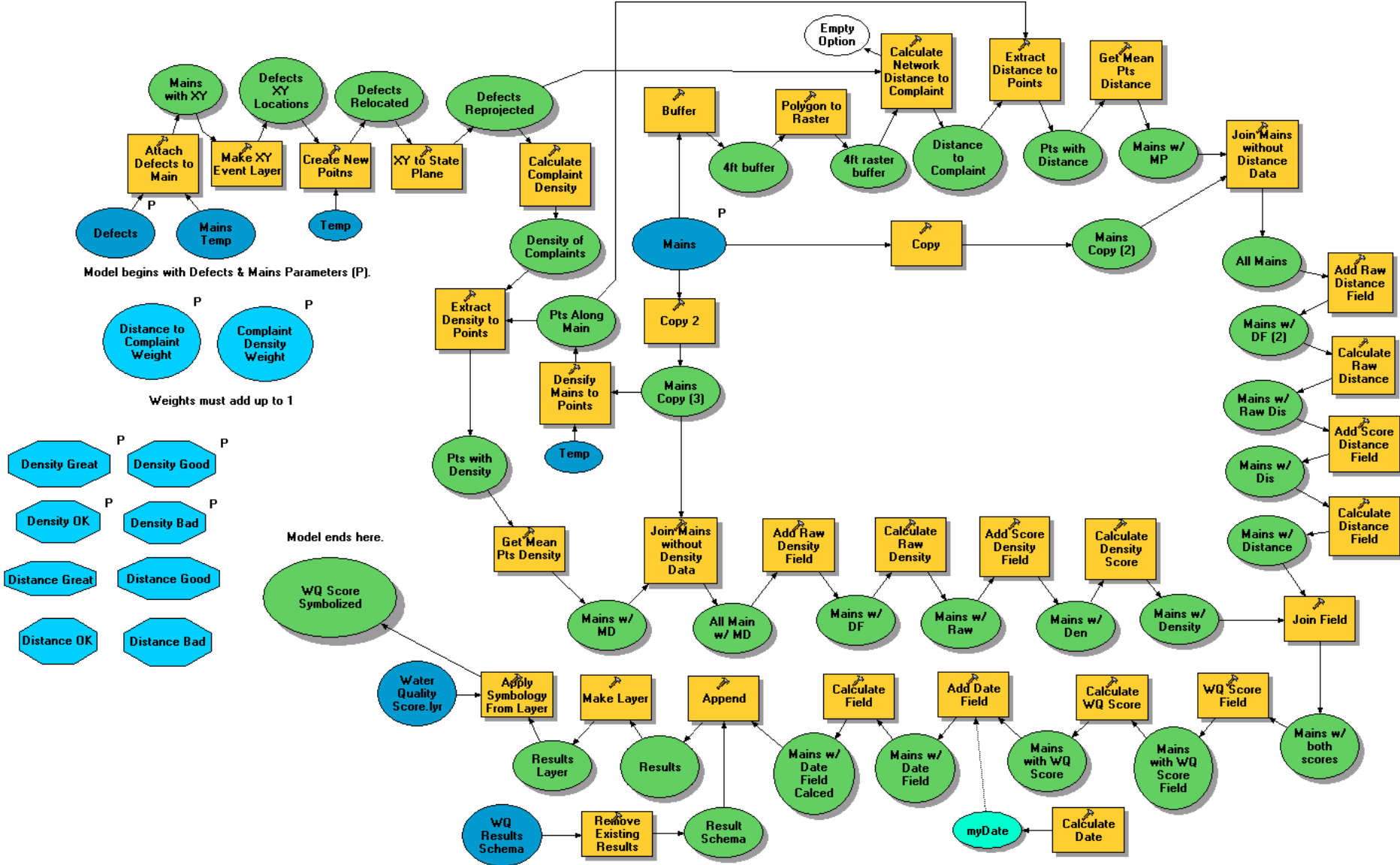


Quality Complaints

- **Measures:**
 - § Distance to nearest quality related complaint
 - § Density rate of local quality related complaints
- **Reason:**
 - § *Properly sorted* complaints are one indicator of failing infrastructure.
- **Input / Output:**

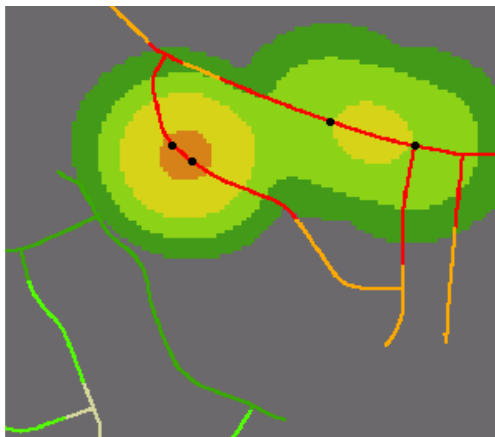
<i>o = optional</i> <i>Date = Date of Occurance</i> <i>(or) Date of Install</i>	Attribute Fields									
	Date	Diameter	Material	GUID	Raw Distance	Distance Score	Raw Density	Density Score	Score	Run Date
Inputs										
WQ Complaint Points	✓	-	-	-	-	-	-	-	-	-
Water Mains	✓	✓	✓	✓	-	-	-	-	-	-
Output										
Quality Score Layer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Water Quality Model





Water Quality Distance & Density Analysis



Distance
In Feet

1 > 2401

2 1801 - 2400

3 1201 - 1800

4 601 - 1200

5 < 600

Density
Per Sq. Mile

1 1 - 40

2 41 - 125

3 126 - 275

4 276 - 575

5 576 >

- **Distance:**
 - § Measures distance through the network to nearest complaint.
- **Density:**
 - § Measures “intensity” of complaints.
- **(Density Score * 80%) + (Distance Score * 20%) = Water Quality Score**

Grade

A

B

C

D

E



GCIP - Study Area WQ Model Run

Grade

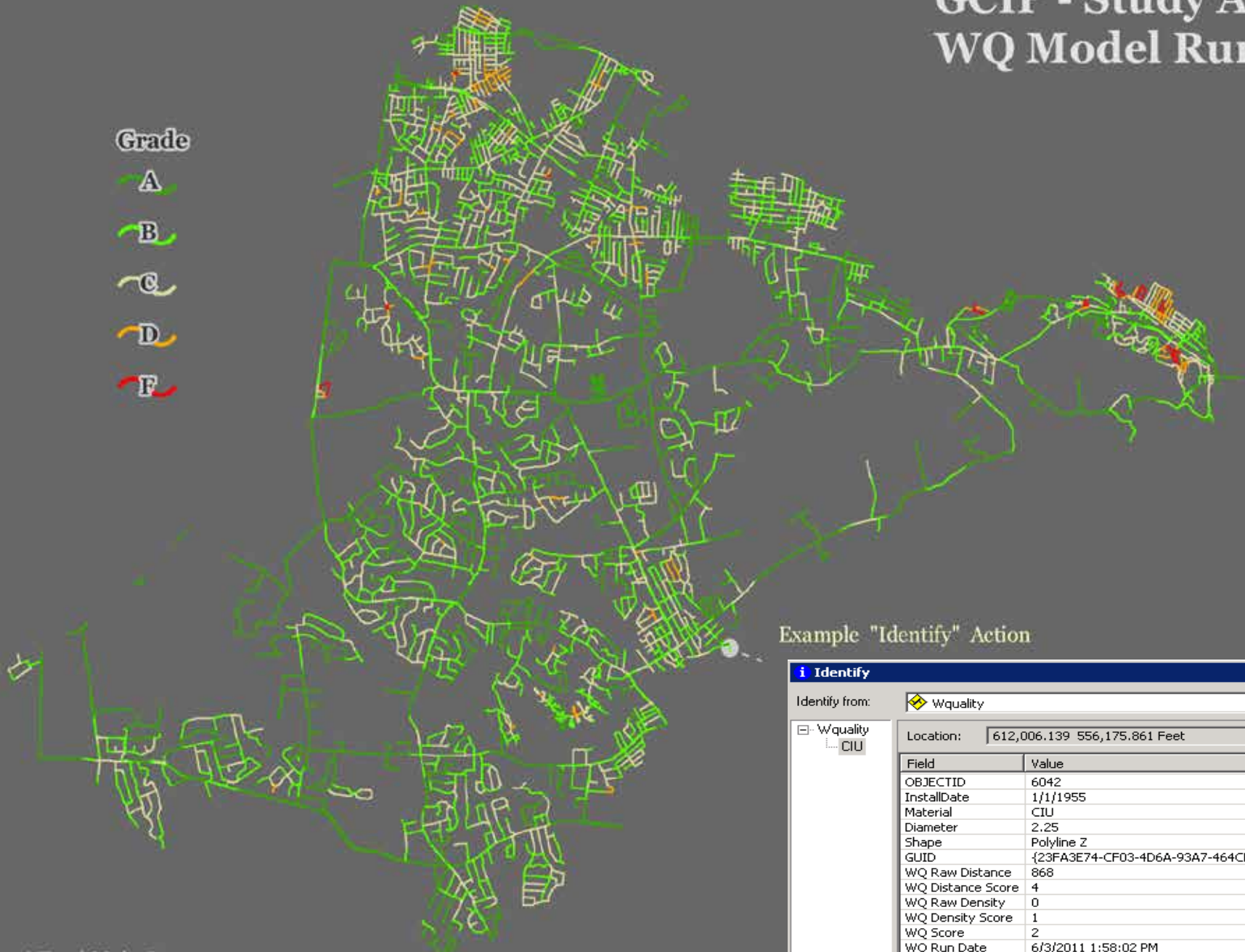
A

B

C

D

F



Example "Identify" Action

i Identify [?] [X]

Identify from: Wquality

Location: 612,006.139 556,175.861 Feet

Field	Value
OBJECTID	6042
InstallDate	1/1/1955
Material	CIU
Diameter	2.25
Shape	Polyline Z
GUID	{23FA3E74-CF03-4D6A-93A7-464CBB034FF9}
WQ Raw Distance	868
WQ Distance Score	4
WQ Raw Density	0
WQ Density Score	1
WQ Score	2
WQ Run Date	6/3/2011 1:58:02 PM
Shape_Length	284.533534



Life Expectancy

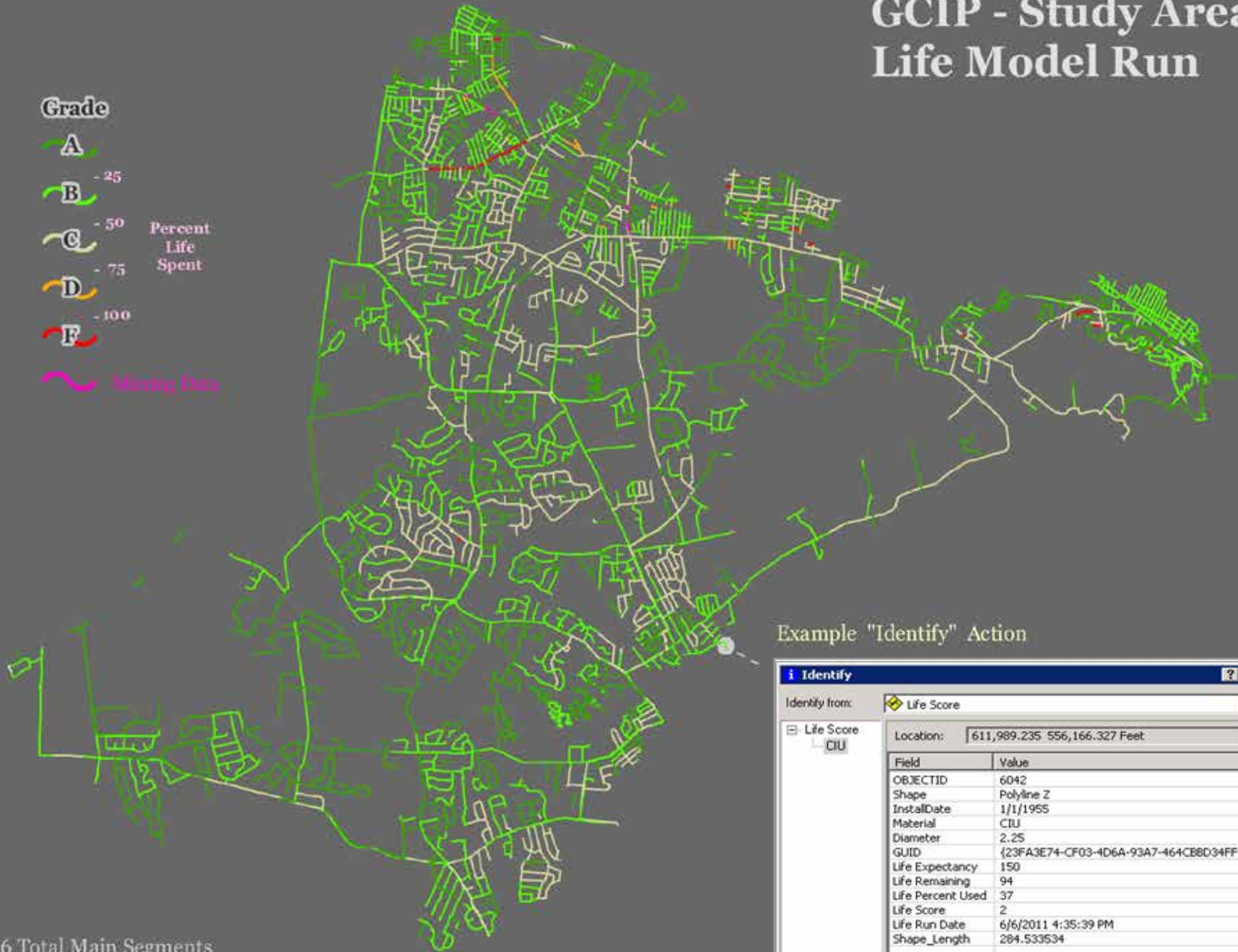
- **Measures:**
 - § The percent of life spent per segment.
- **Reason:**
 - § Life expectancy can be a predictor of future breaks.
- **Input / Output:**

<i>a = optional</i> <i>Date = Date of Occurrence</i> <i>(or) Date of Install</i>	Attribute Fields								
	Date	Diameter	Material	GUID	Life Expectancy	Life Remaining	Percent Spent	Score	Run Date
Inputs									
Life Expectancy Table	-	-	✓	-	✓	-	-	-	-
Water Mains	✓	✓	✓	✓	-	-	-	-	-
Output									
Life Score Layer	✓	✓	✓	✓	✓	✓	✓	✓	✓

GCIP - Study Area Life Model Run

Grade

- A** - 25
 - B** - 50
 - C** - 75
 - D** - 100
 - E** - 100
 - F** - Missing Data
- Percent Life Spent



Example "Identify" Action

i Identify	
Identify from:	Life Score
Life Score	CIU
Location:	611,989.235 556,166.327 Feet
Field	Value
OBJECTID	6042
Shape	Polyline Z
InstallDate	1/1/1955
Material	CIU
Diameter	2.25
GUID	{23FA3E74-CF03-4D6A-93A7-464CB8D34FF9}
Life Expectancy	150
Life Remaining	94
Life Percent Used	37
Life Score	2
Life Run Date	6/6/2011 4:35:39 PM
Shape_Length	284.533534



Critical Points

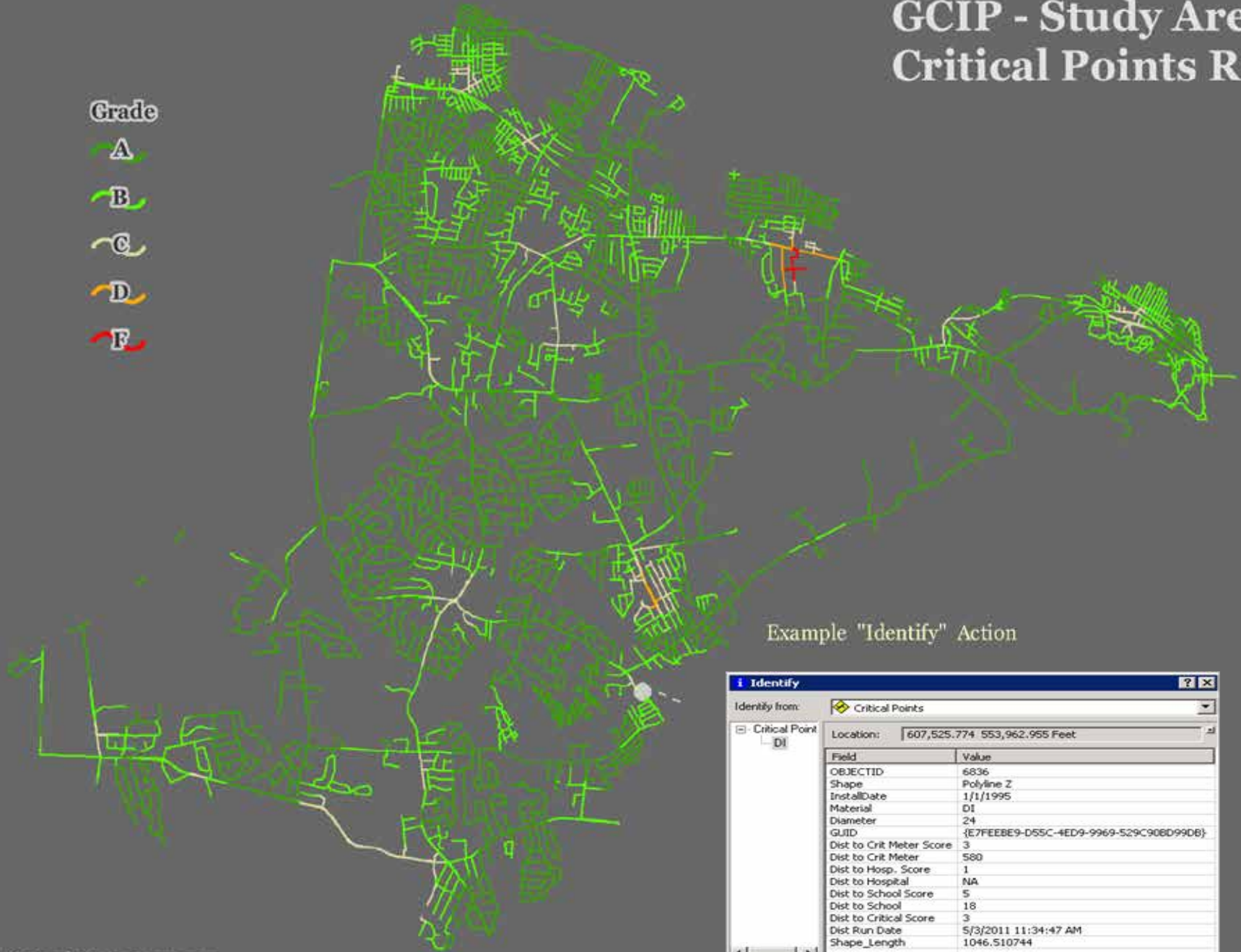
- **Measures:**
 - § The distance to three categories of critical points.
- **Reason:**
 - § Outages near certain areas (e.g., hospitals, schools, or industry) are more expensive and/or disruptive to company & public.
- **Input / Output:**

<i>α = optional</i> Date = Date of Occurance (or) Date of Install	Attribute Fields											
	Date	Diameter	Material	GUID	Hospital Distance	Hospital Score	School Distance	School Score	Meter Distance	Meter Score	Score	Run Date
Inputs												
Hospitals	-	-	-	-	-	-	-	-	-	-	-	-
Schools	-	-	-	-	-	-	-	-	-	-	-	-
Major Meter	-	-	-	-	-	-	-	-	-	-	-	-
Parcels	-	-	-	-	-	-	-	-	-	-	-	-
Water Mains	✓	✓	✓	✓	-	-	-	-	-	-	-	-
Output												
Critical Score Layer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

GCIP - Study Area Critical Points Run

Grade

- A
- B
- C
- D
- E



Example "Identify" Action

Identify

Identify from: Critical Points

Critical Point [D]

Location: 607,525.774 553,962.955 Feet

Field	Value
OBJECTID	6836
Shape	Polyline Z
InstallDate	1/1/1995
Material	D1
Diameter	24
GUID	{E7FEEBE9-D55C-4ED9-9969-529C90BD99DB}
Dist to Crit Meter Score	3
Dist to Crit Meter	580
Dist to Hosp. Score	1
Dist to Hospital	NA
Dist to School Score	5
Dist to School	18
Dist to Critical Score	3
Dist Run Date	5/3/2011 11:34:47 AM
Shape_Length	1046.510744

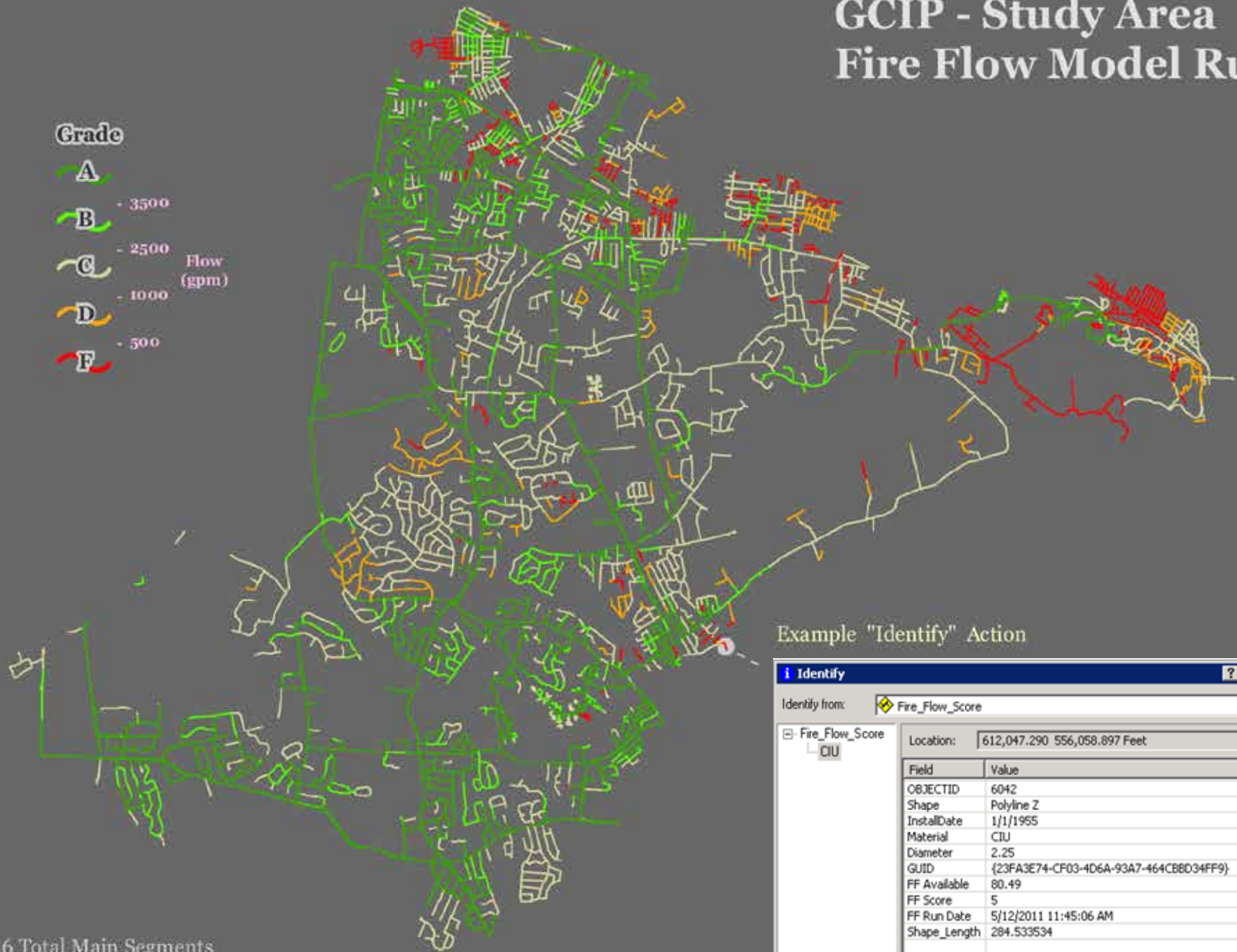


Fire Flow

- **Measures:**
 - § Available fire flow.
- **Reason:**
 - § Low fire flow can be indicator of undersized and/or failing infrastructure.
- **Input / Output:**

<i>a = optional</i> <i>Date = Date of Occurrence</i> <i>(or) Date of Install</i>	Attribute Fields						
	Date	Diameter	Material	GUID	Fire Flow Available	Score	Run Date
Inputs							
Fire Flow Nodes	-	-	-	-	✓	-	-
Water Mains	✓	✓	✓	✓	-	-	-
Output							
Fire Flow Score Layer	✓	✓	✓	✓	✓	✓	✓

GCIP - Study Area Fire Flow Model Run



Identify from: Fire_Flow_Score

Fire_Flow_Score
CIU

Location: 612,047.290 556,058.897 Feet

Field	Value
OBJECTID	6042
Shape	Polyline Z
InstallDate	1/1/1955
Material	CIU
Diameter	2.25
GUID	{23FA3E74-CF03-4D6A-93A7-464C8B034FF9}
FF Available	80.49
FF Score	5
FF Run Date	5/12/2011 11:45:06 AM
Shape_Length	284.533534

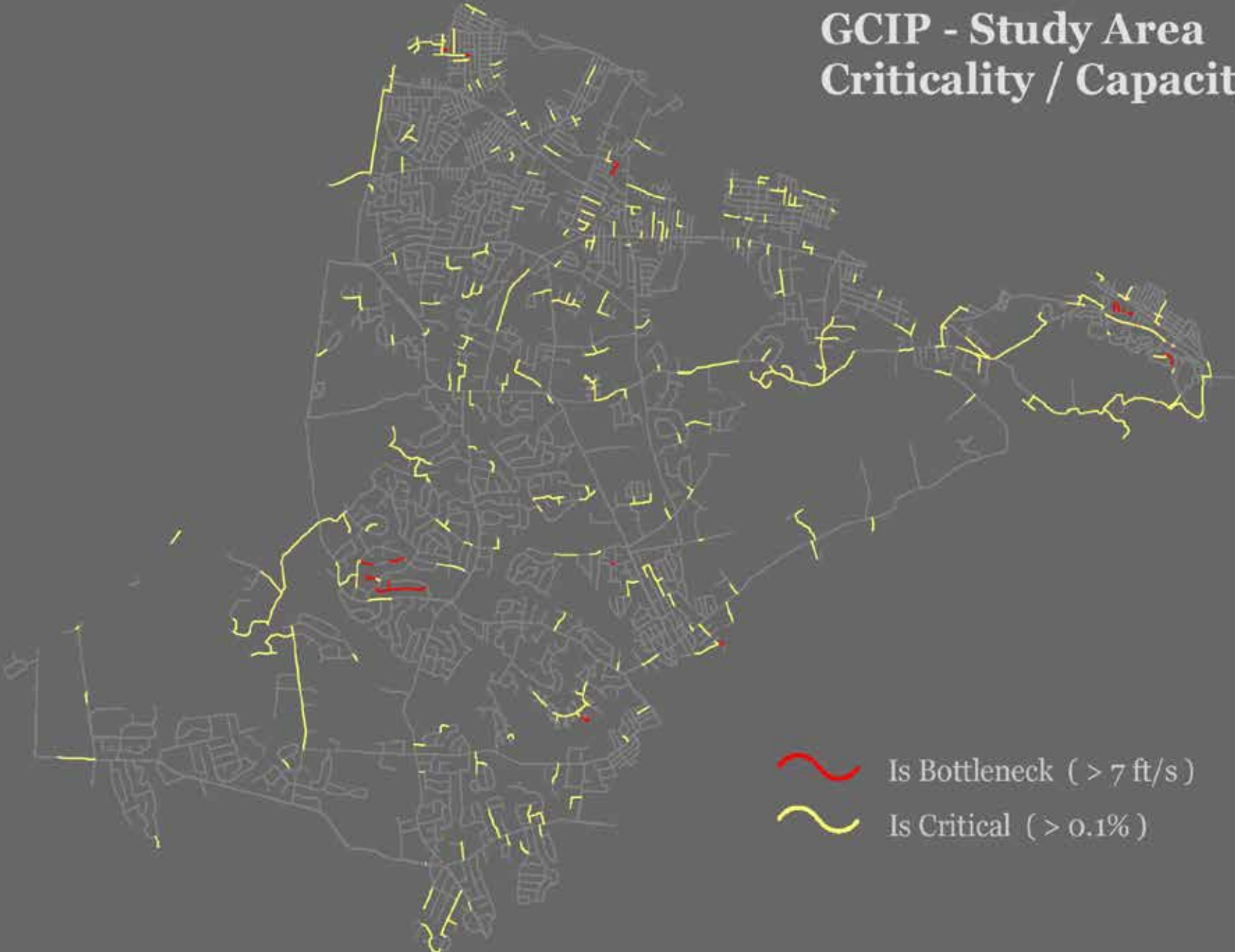


Hydraulic (Criticality & Capacity)

- **Measures:**
 - § Criticality - Percent system loss if main segment is out of service.
 - § Capacity - Mean velocity per segment during Max Day fire flow.
 - § Smaller # of mains effected by this model.
 - § Only model not scored or weighted.
- **Reason:**
 - § Political & Monetary cost avoidance of overly disruptive outages or coverage failures.
 - § Input / Output:

<i>α = optional</i> <i>Date = Date of Occurance (α)</i> <i>Date of Install</i>	Attribute Fields									
	Date	Diameter	Material	GUID	Raw Criticality	Raw Capacity	Is Critical?	Is Bottleneck?	Score	Run Date
Inputs										
Criticality / Capacity	✓	✓	✓	✓	✓	✓	-	-	-	-
Water Mains	✓	✓	✓	✓	-	-	-	-	-	-
Output										
Repair Score Layer	✓	✓	✓	✓	✓	✓	✓	✓	-	✓

GCIP - Study Area Criticality / Capacity





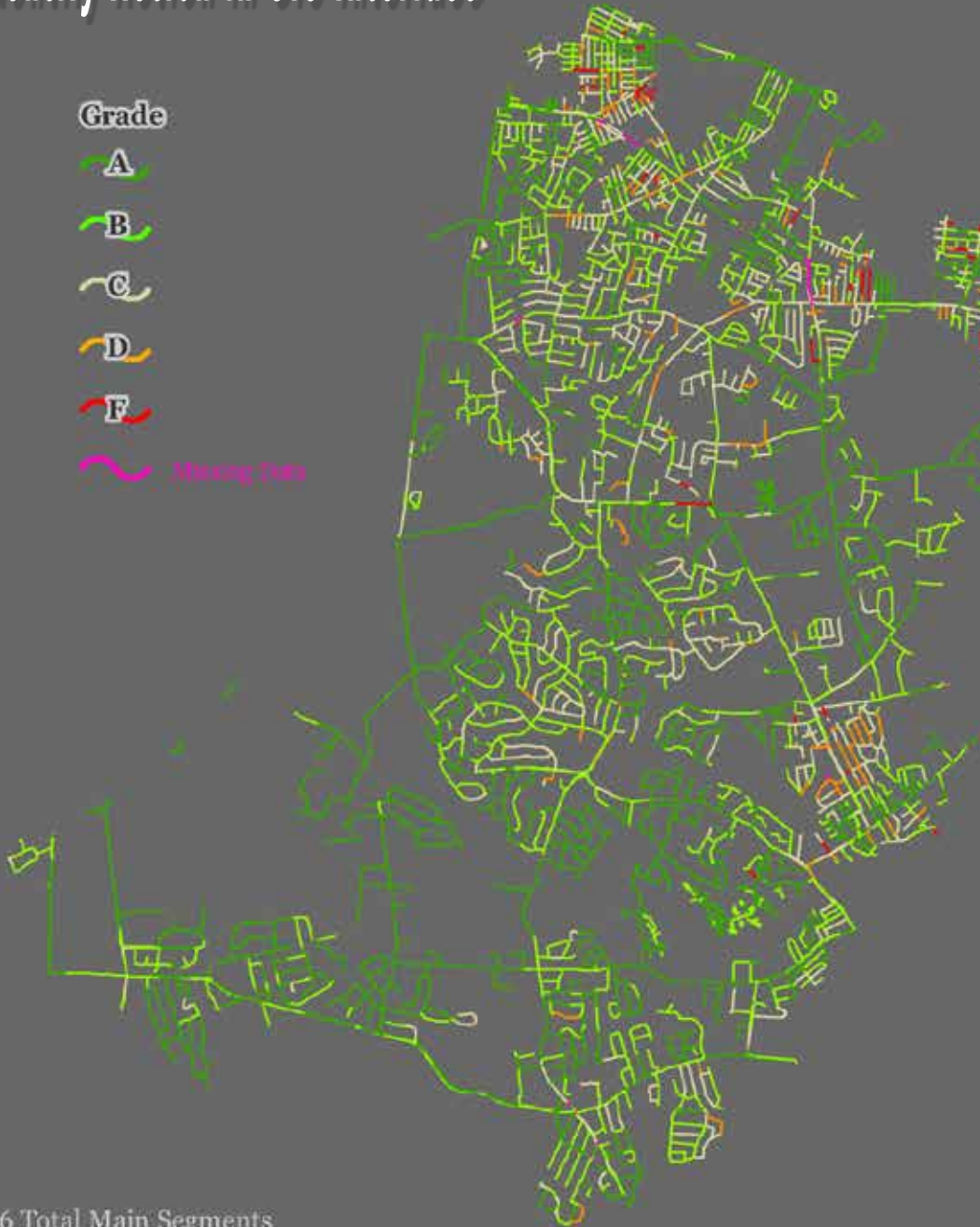
Weighted Overlay

- **Measures:**
 - § The numeric total of user weighted scores for Repair, Quality, Life, Critical Points, and Fire Flow models.
 - § Criticality & Capacity analysis results appended.
- **Reason:**
 - § Weights provide flexibility for situational user analysis needs.
 - § Common grade scale ranking allows for objective multivariate comparison, which can be a valuable planning tool.
 - § Appended hydraulic results individually identify potential hydraulically critical infrastructure within the comprehensive scores.

Weighted Overlay Input / Output

* Indicates the field exists with a unique name for each input category.	Attributes															
	Date	Diameter	Material	GUID	Repair Group	Quality Group	Life Group	Critical Group	Fire Flow Group	Hydro Group	Score*	Run Date*	Weight**	Weighted Score**	Overlay Score	
Inputs																
Repair Layer	✓	✓	✓	✓	✓	-	-	-	-	-	✓	✓	-	-	-	
Quality Layer	✓	✓	✓	✓	-	✓	-	-	-	-	✓	✓	-	-	-	
Life Layer	✓	✓	✓	✓	-	-	✓	-	-	-	✓	✓	-	-	-	
Critical Points Layer	✓	✓	✓	✓	-	-	-	✓	-	-	✓	✓	-	-	-	
Fire Flow Layer	✓	✓	✓	✓	-	-	-	-	✓	-	✓	✓	-	-	-	
Hydro Layer	✓	✓	✓	✓	-	-	-	-	-	✓	-	✓	-	-	-	
Output																
Weighted Layer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Raw Value Fields ←															
	Repair Count	Repair Rate	GCIP Rate	Raw Distance	Raw Density	Life Expect	Life Remain	Percent Spent	Hospital Distance	School Distance	Meter Distance	Available Fire Flow	Max Flow Velocity	Is Bottleneck?	Percent Critical	Is Critical?
Field Groups	Repair Group			Quality Group		Life Group			Critical Group			FF Group	Hydraulic Group			
Repair Layer	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-
Quality Layer	-	-	-	✓	✓	-	-	-	-	-	-	-	-	-	-	-
Life Layer	-	-	-	-	-	✓	✓	✓	-	-	-	-	-	-	-	-
Critical Points Layer	-	-	-	-	-	-	-	-	✓	✓	✓	-	-	-	-	-
Fire Flow Layer	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-
Hydro Layer	-	-	-	-	-	-	-	-	-	-	-	-	✓	✓	✓	✓

Identify Action in GIS Interface



i Identify

Identify from: Weighted Overlay Group

Predictive

Location: 625,344.623 569,444.080 Feet

Field	Value
OBJECTID	3029
Shape	Polyline Z
InstallDate	1/1/1935
Material	DI
Diameter	6
GUID	{112BA818-7EC3-4E1F-B363-7DAADA064B07}
FF Available	440.32
FF Score	5
FF Run Date	5/12/2011 11:45:06 AM
FF User Weight	15%
Weighted FF Score	0.75
Life Expectancy	110
Life Remaining	34
Life Percent Used	69.090909
Life Score	3
Life Run Date	6/6/2011 4:35:39 PM
Life User Weight	30%
Weighted Life Score	0.9
Dist to Crit Meter Score	1
Dist to Crit Meter	NA
Dist to Hosp_Score	1
Dist to Hospital	NA
Dist to School Score	1
Dist to School	NA
Dist to Critical Score	1
Dist Run Date	5/3/2011 11:34:47 AM
Distance User Weight	0%
Weighted Dist Crit Score	0
WQ Avg Distance	<null>
WQ Avg Density	<null>
WQ Score	3
WQ Run Date	6/3/2011 1:58:02 PM
WQ User Weight	25%
Weighted WQ Score	0.75
Repair Count	1
Repair Rate (m/y)	0.41
Repair Rate (yrs)	15
Repair Score	2
Repair Run Date	6/27/2011 10:50:26 AM
Repair User Weight	30%
Weighted Repair Score	0.6
FFvelocity	< 7
Is Bottleneck?	No
Criticality %	0
Is Critical?	No
Hydro Run Date	6/24/2011 10:56:00 AM
Weighted Overlay Score	3
Overlay Run Date	6/29/2011 10:41:34 AM
Shape_Length	853.273718

Poor Only

GCIP - Study Area Weighted Overlay

Grade "D" & "F"

Grade

A

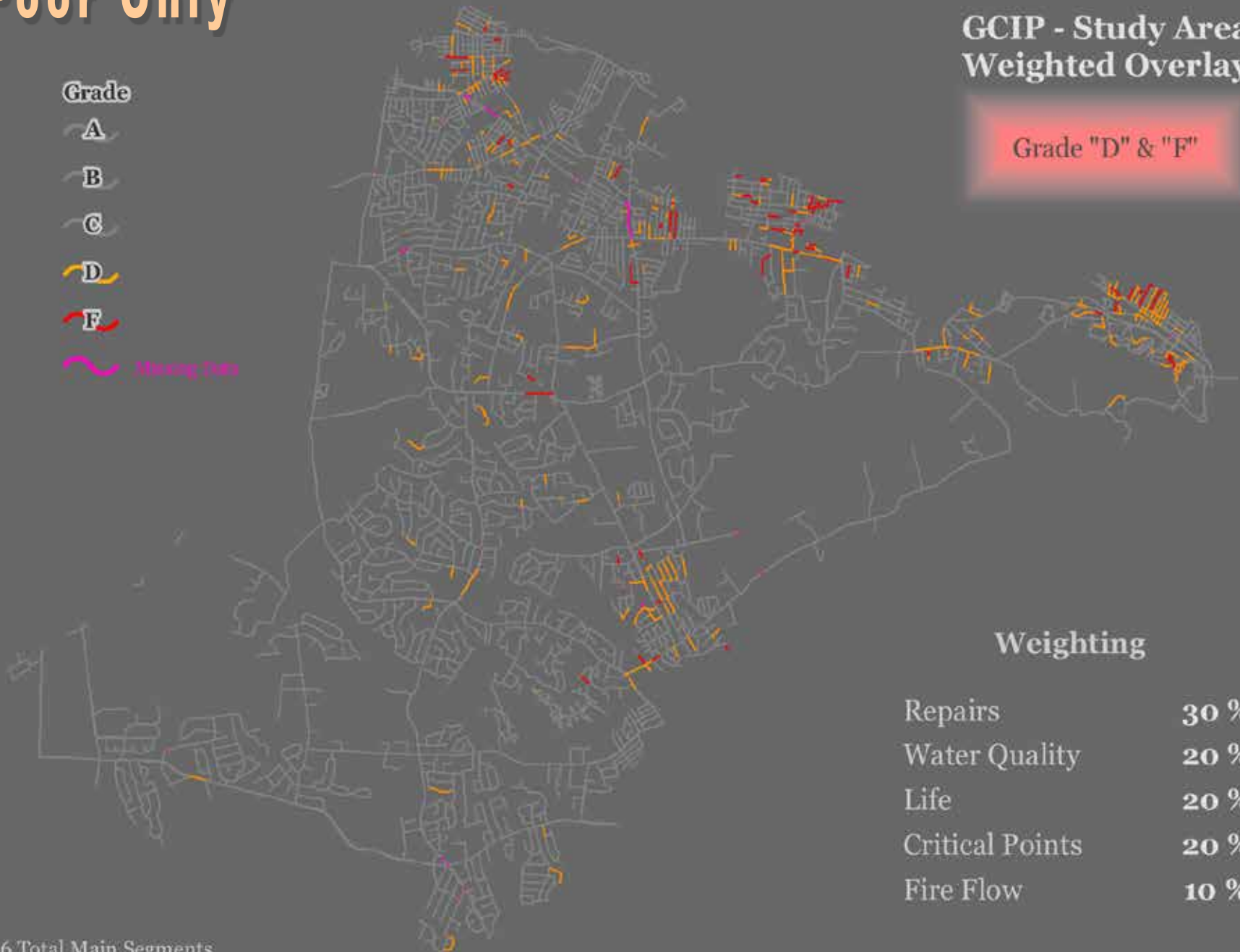
B

C

D

F

Missing Data



Weighting

Repairs 30 %

Water Quality 20 %

Life 20 %

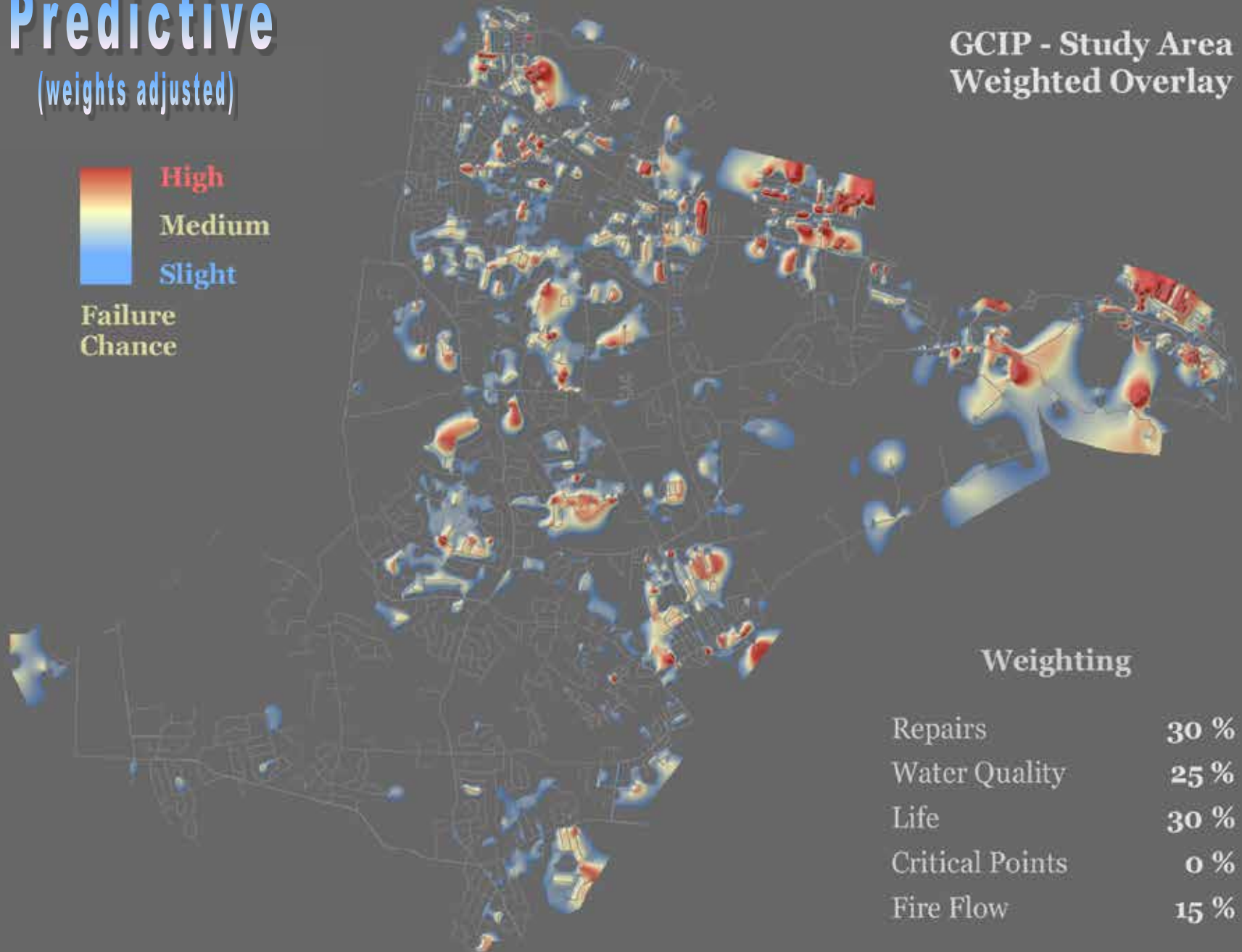
Critical Points 20 %

Fire Flow 10 %

Predictive

(weights adjusted)

GCIP - Study Area Weighted Overlay



Weighting

Repairs	30 %
Water Quality	25 %
Life	30 %
Critical Points	0 %
Fire Flow	15 %



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AMERICAN WATER



Questions?

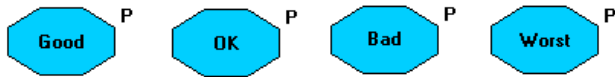


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Model Diagrams

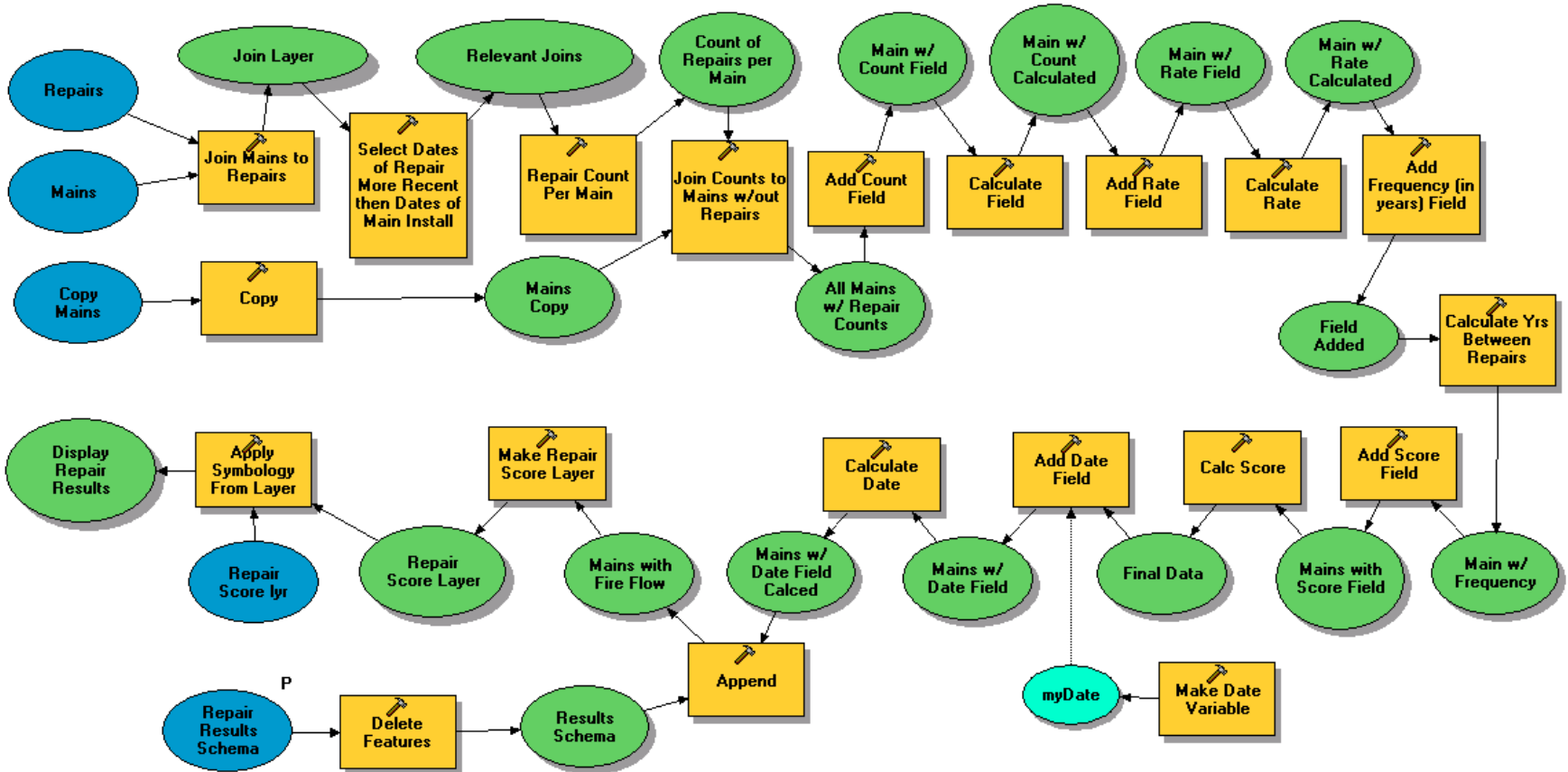
Repair Model



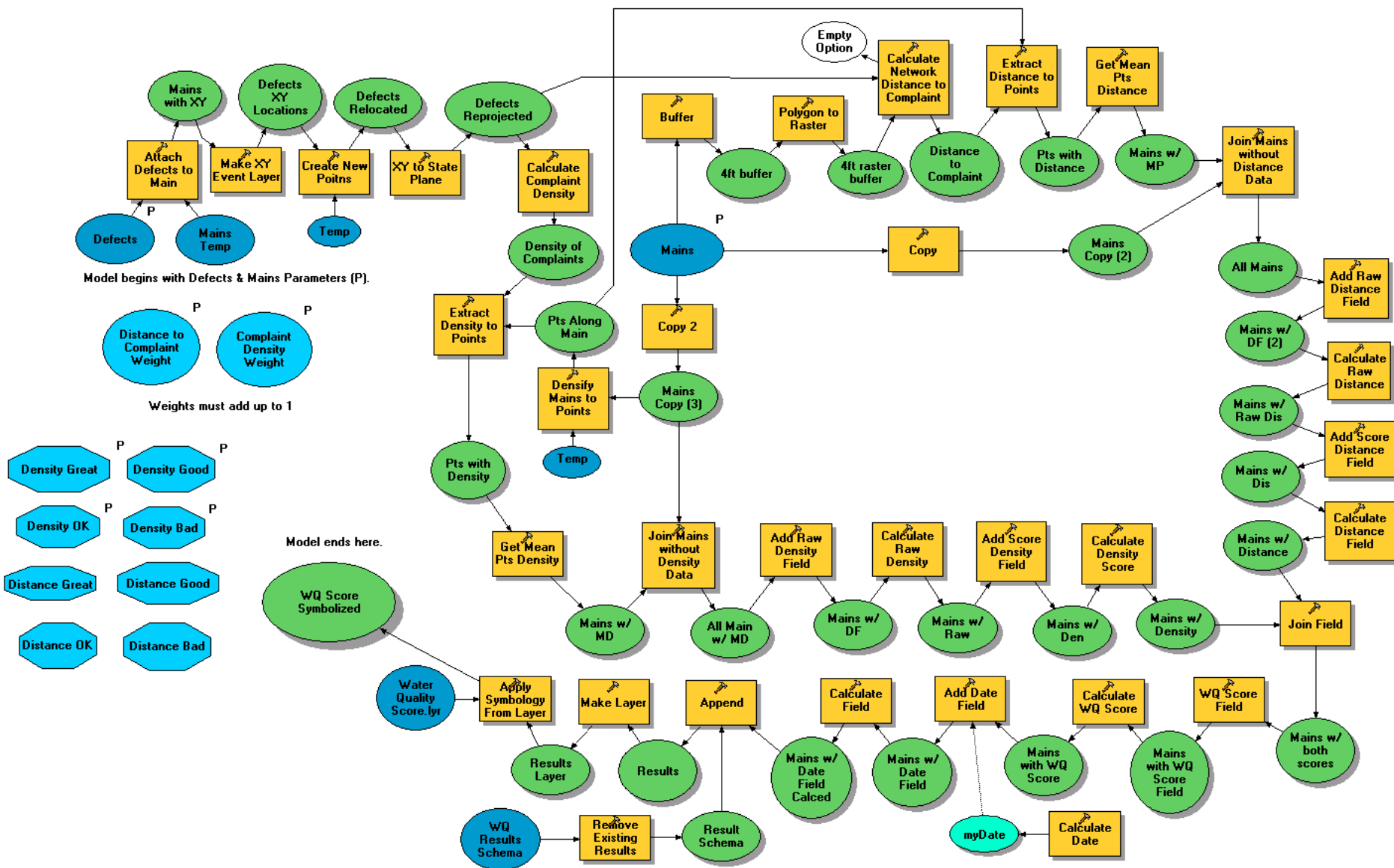
Calc Score Variables

Use Class Breakpoints for Calc Score Variables. User can adjust. Suggest using a modified Jenk's breaks from Repair Frequency Field.

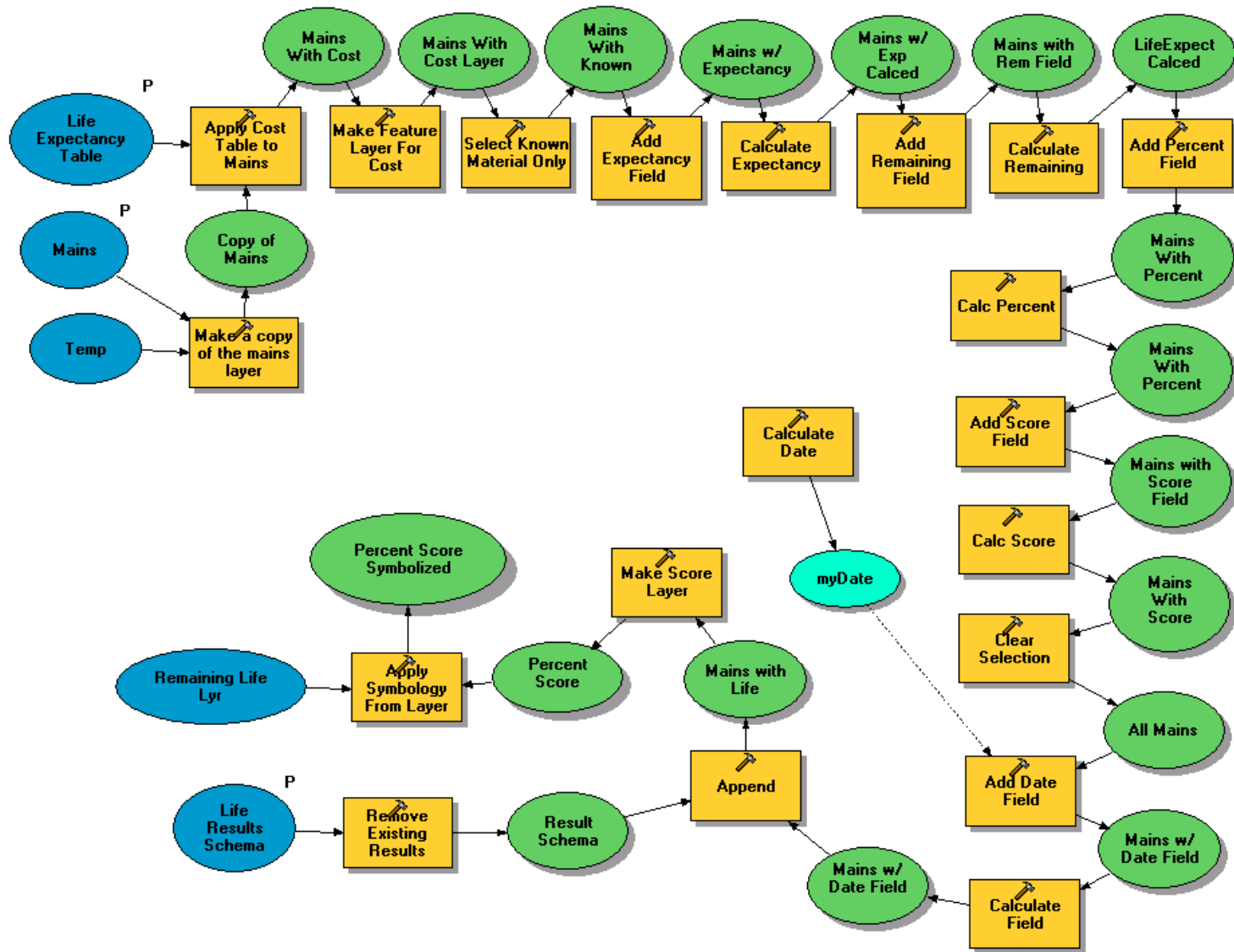
Use Total Years of Repair History for "Good". This will ensure that all mains with at least one repair do not get a perfect score. Use lowest Jenk's break point for "Worst"



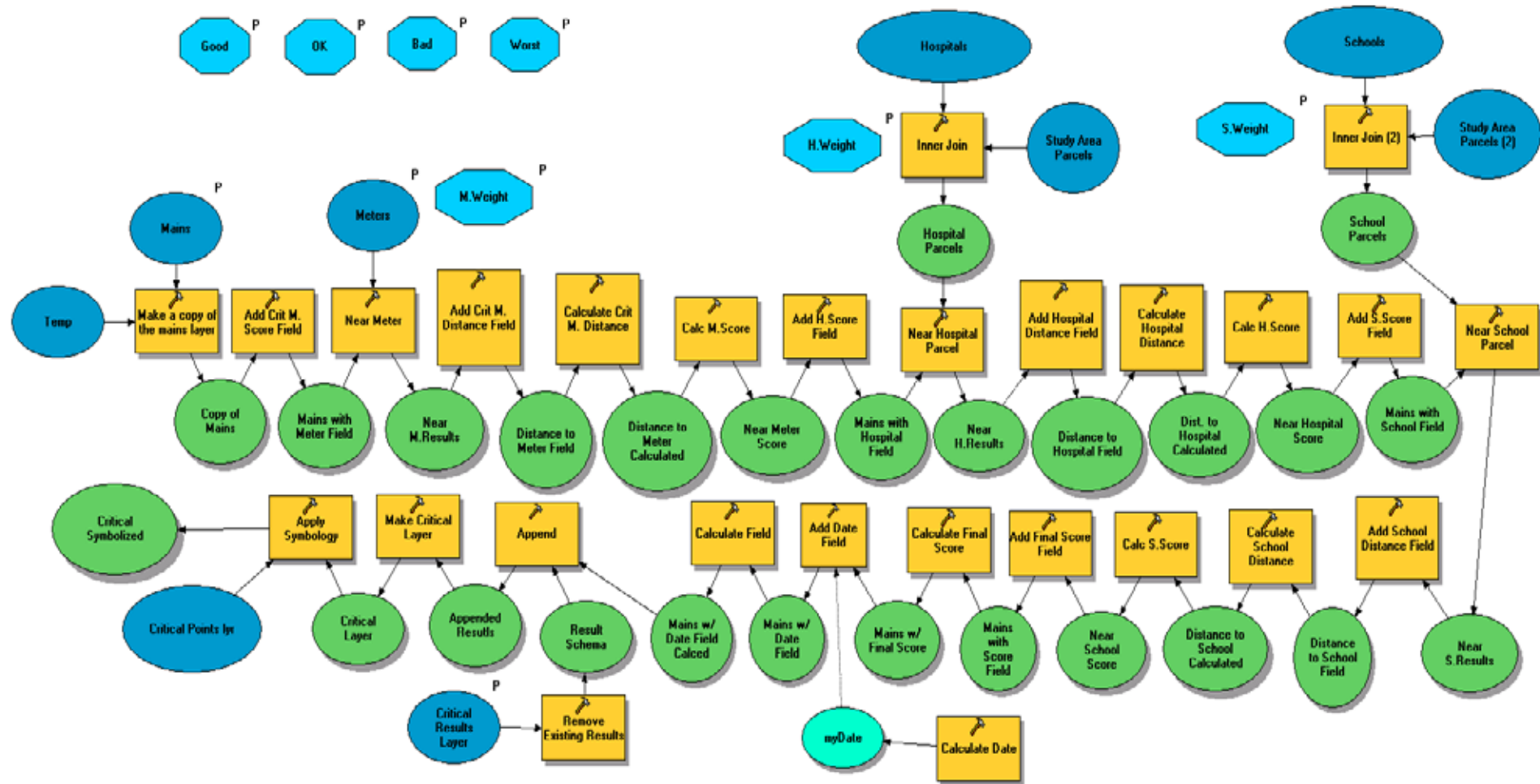
Water Quality Model



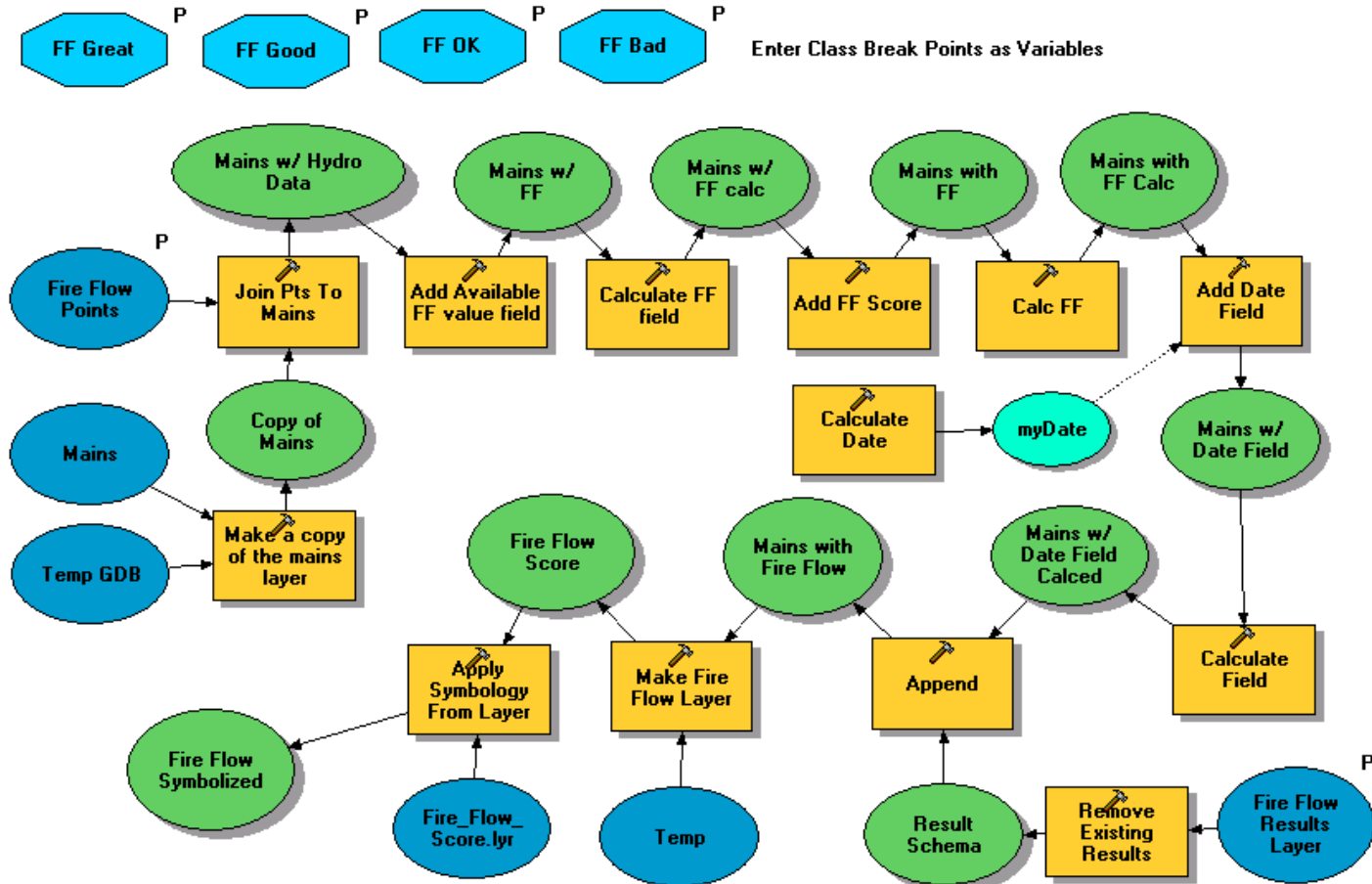
Life Model



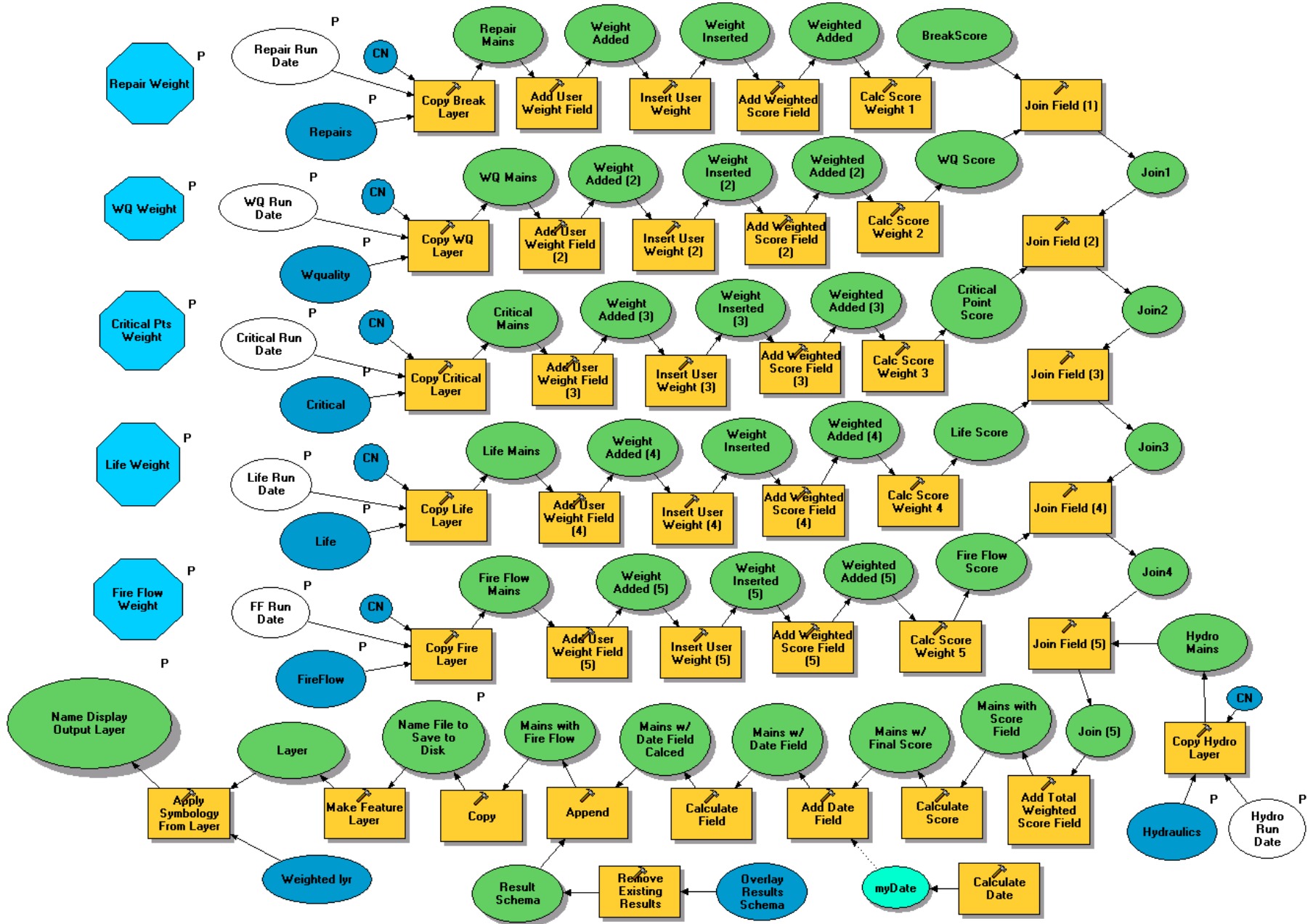
Critical Points Model



Fire Flow Model

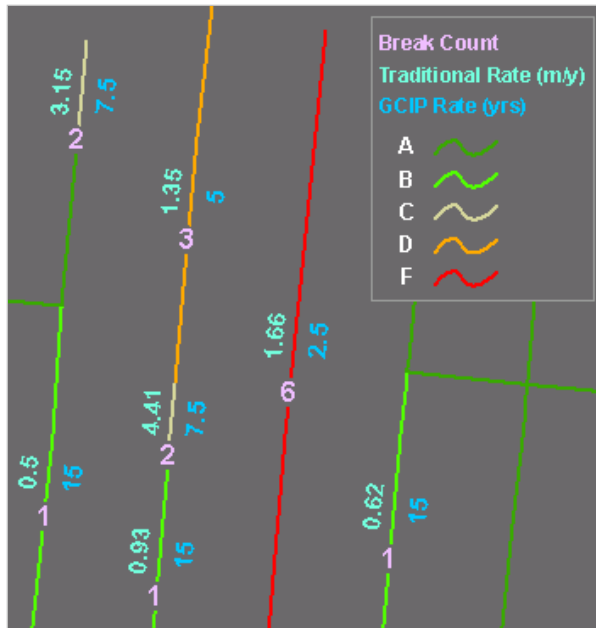


Weighted Overlay Model





Break Rate Equations



- **Traditional Rate**

- § Included for “pipe class” summary data or “regional” analysis
- § $RR = \text{Repair Count} / (\text{Segment Length in ft} / 5,280) / \text{Duration}$
- § Answer Reads:
 - “X breaks per mile per year”
- § **Highly Variable** by segment length
- § **Not Desirable** for segment based “Grade” scoring

- **GCIP Rate** (inverse frequency)

- History = "1/1/1996" *set as oldest repair history date available*
- $x = \text{DateDiff}(\text{"yyyy"}, [\text{Install Date}], \text{now})$
- $y = \text{DateDiff}(\text{"yyyy"}, \text{History}, \text{now})$
- If $x < y$ then
- Solution = $1 / ([\text{Repair Count}] / x)$
- Else
- Solution = $1 / ([\text{Repair Count}] / y)$
- Endif
- § **GCIP Answer Reads:**
 - "This main breaks every X years."
 - **Desirable** for segment based “Grade” scoring



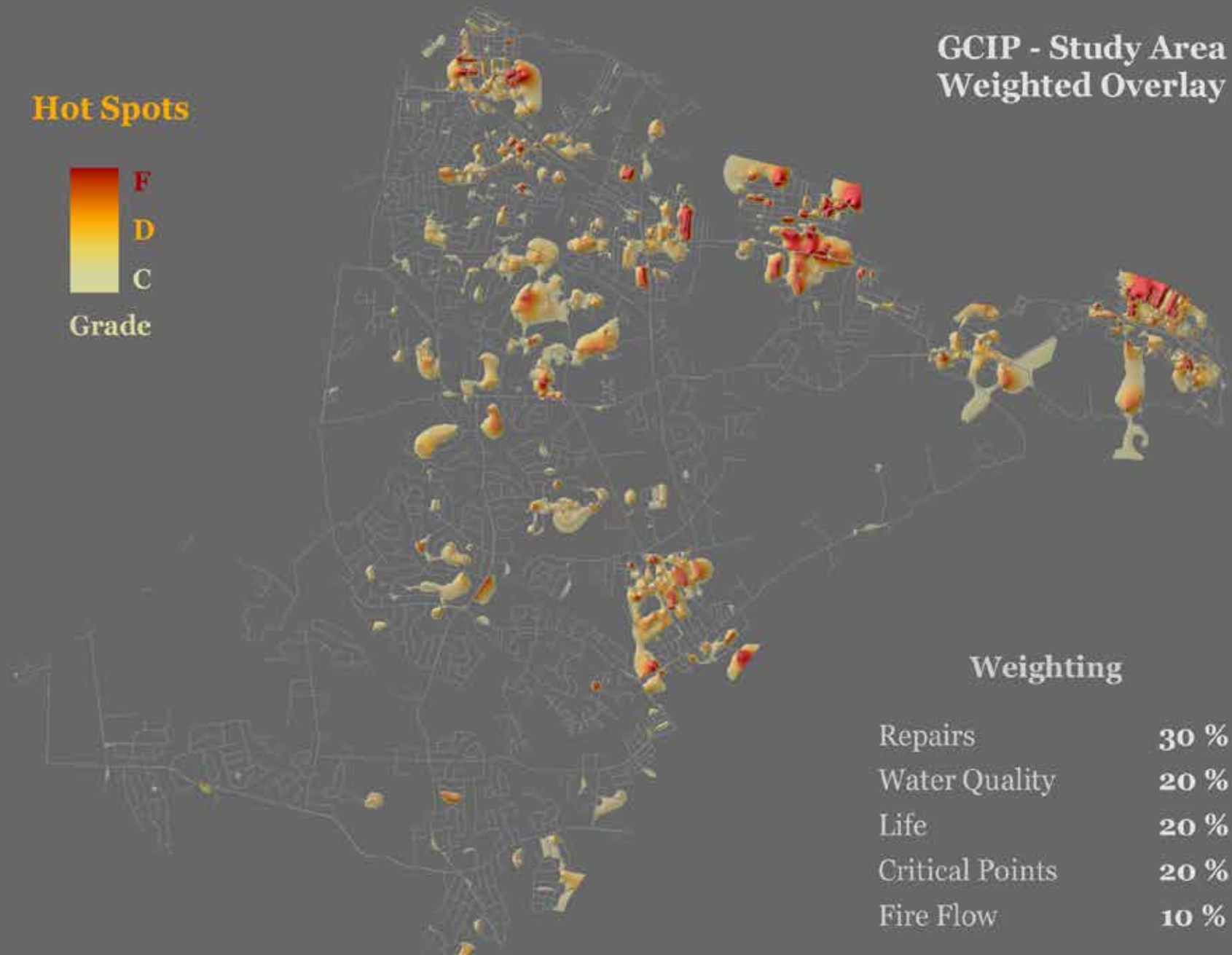
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Various Overlay Map Display Options

GCIP - Study Area Weighted Overlay

Hot Spots



Weighting

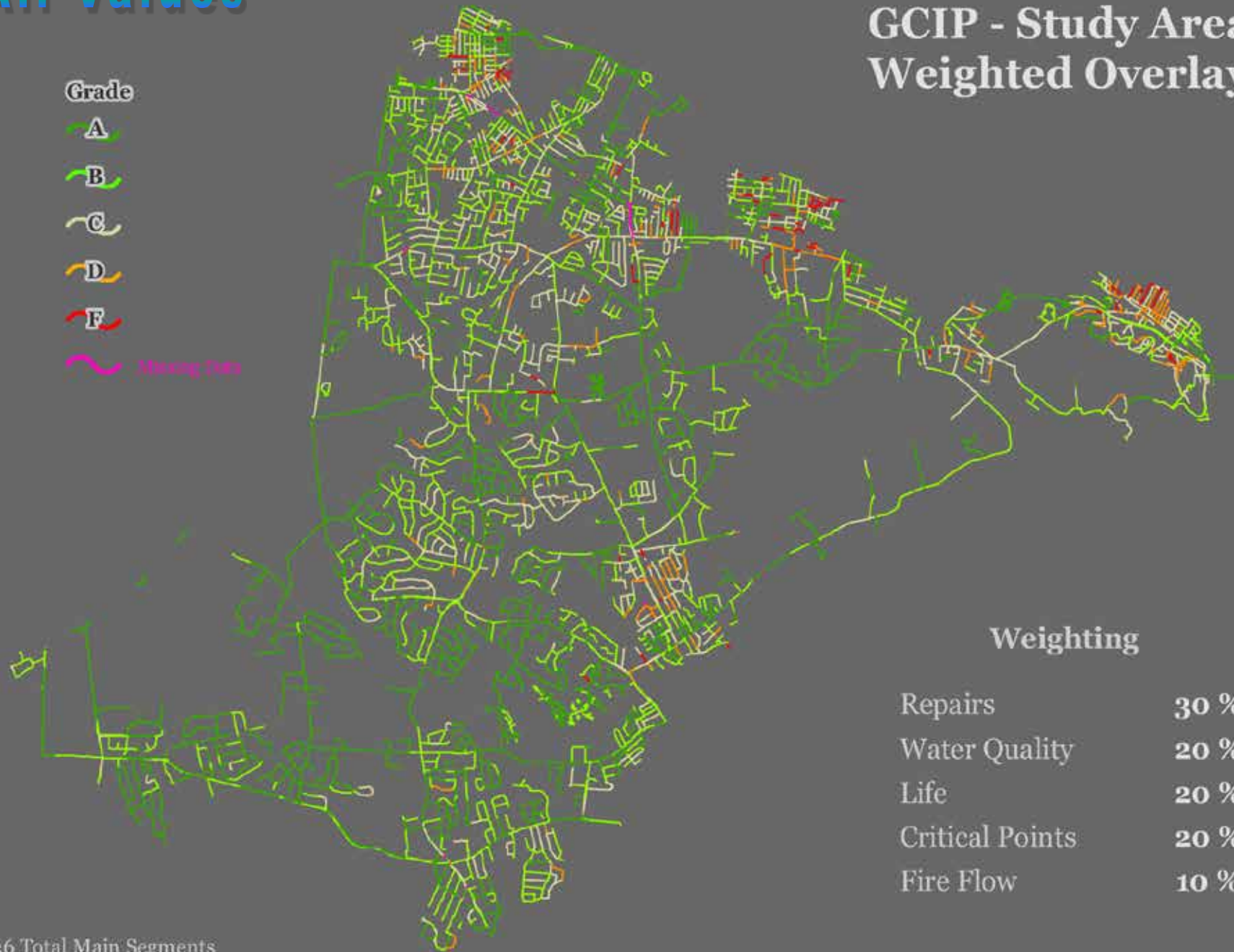
Repairs	30 %
Water Quality	20 %
Life	20 %
Critical Points	20 %
Fire Flow	10 %

All Values

GCIP - Study Area Weighted Overlay

Grade

- A
- B
- C
- D
- F
- Missing Data



Weighting

Repairs	30 %
Water Quality	20 %
Life	20 %
Critical Points	20 %
Fire Flow	10 %



Opportunities for Improvement

- **Changes to Life Model**
 - § Replace with Condition Based Assessment (CBA) Model
 - § Requires much more data in GIS format
- **Changes to Repair Model**
 - § Weight Main Break by Repair Cost
 - § Tolerance of repair rate can vary greatly depend on type & location of water main break
- **Changes to All Models**
 - § Add more scoring classes
 - § Will add more resolution to analysis
 - § Final maps can still be summarized into 5 classes for visualization