

# Time Value of Money and Optimization Process

# Cost Definitions

- Inflation – increase in cost of products over time, decrease of purchasing power
- Recurring cost – a cost that happens multiple times at regular intervals (ie - rent, car loan repayment, tuition and fees, maintenance)
- Capital cost – one time cost (ie – construction, permit, machinery purchase)
- Present worth – equivalent present value of future or recurring costs

# Inflation

Money loses purchasing power over time

- Average price of milk in 1995 = \$2.48
  - Average price of milk in 2016 = \$3.17
  - Average annual increase = 1%
- 
- Average price of unleaded gasoline in 1976 = \$0.61
  - Average price of unleaded gasoline in 2016 = \$2.10
  - Average annual increase = 1.7%

Usually estimate average annual inflation = 3%

# Capital Expense

- Initial, one-time cost
- Design, excavation, piping, rainwater harvest tank, construction...
- Assumes that components will last a certain period of time
- Already in present worth

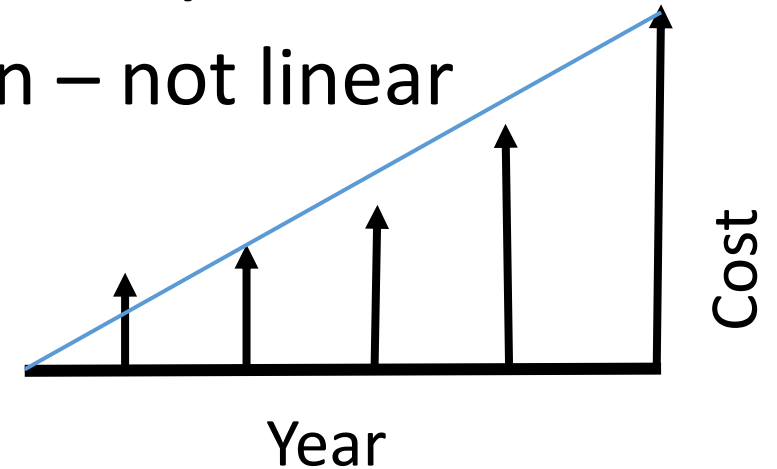
# Recurring Expense

- A cost that happens multiple times at regular intervals
- Maintenance – cleaning pervious pavement, weeding, landscaping, replacing mulch layer of a rain garden, sediment and debri removal
- Inflation means maintenance will get more expensive each year

# Present Worth

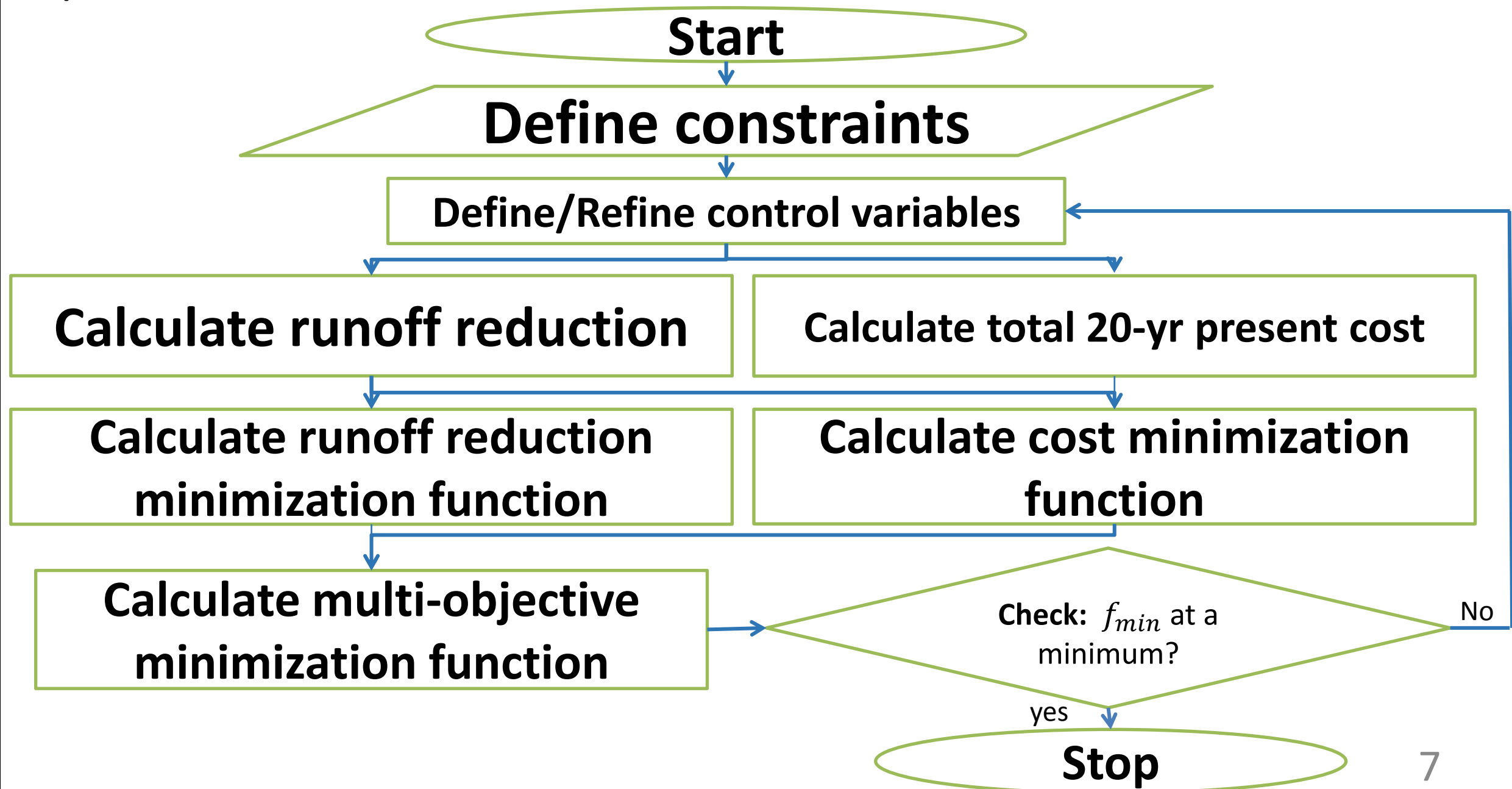
- Inflation → maintenance cost increases each year
- Geometric gradient increase, 3% inflation – not linear

$$P = A_1 \left( \frac{N}{1 + i} \right)$$



- P = Present value
- $A_1$  = First annual payment
- N = Number of years
- i = Interest rate or inflation rate

# Optimization Routine



# Design Constraints

## Fixed constraints

- LID can be implemented only in available space
  - Bioretention and disconnection – limited by pervious area
  - Greenroofs and rainwater harvesting – only on roof area
  - Pervious concrete and pavers – only on streets, parking lots, and sidewalk areas
  - Pervious asphalt – only on streets and parking lots

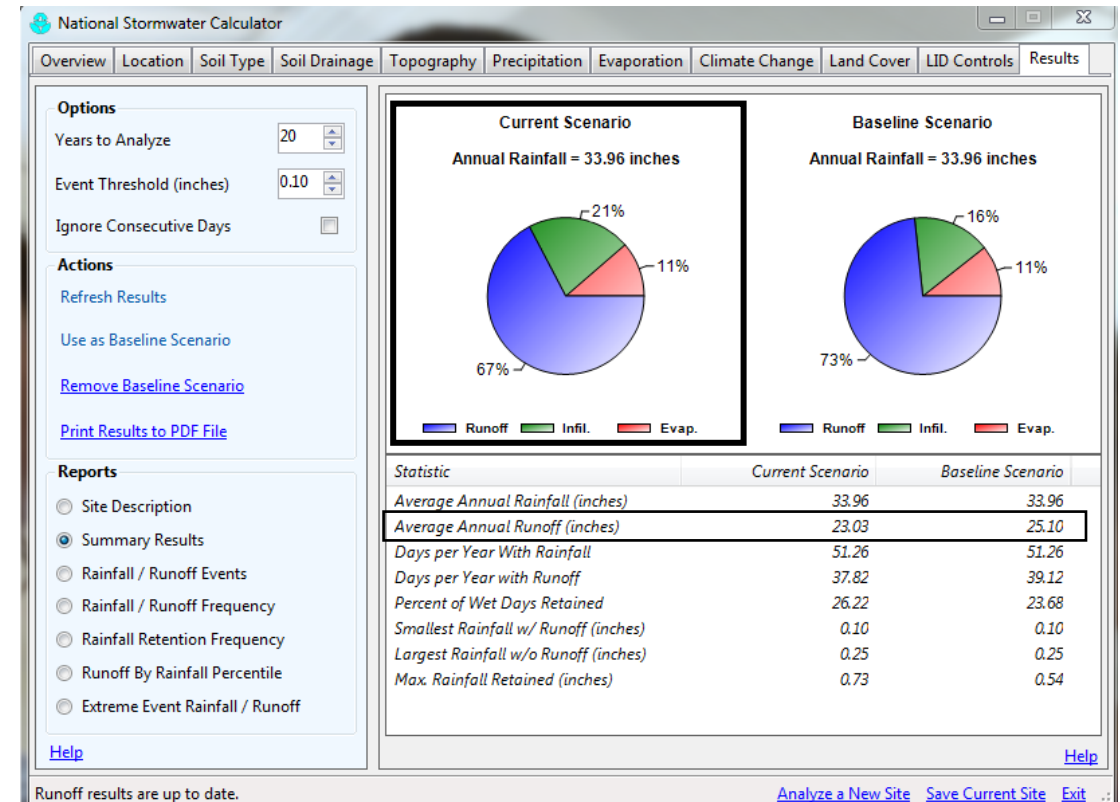
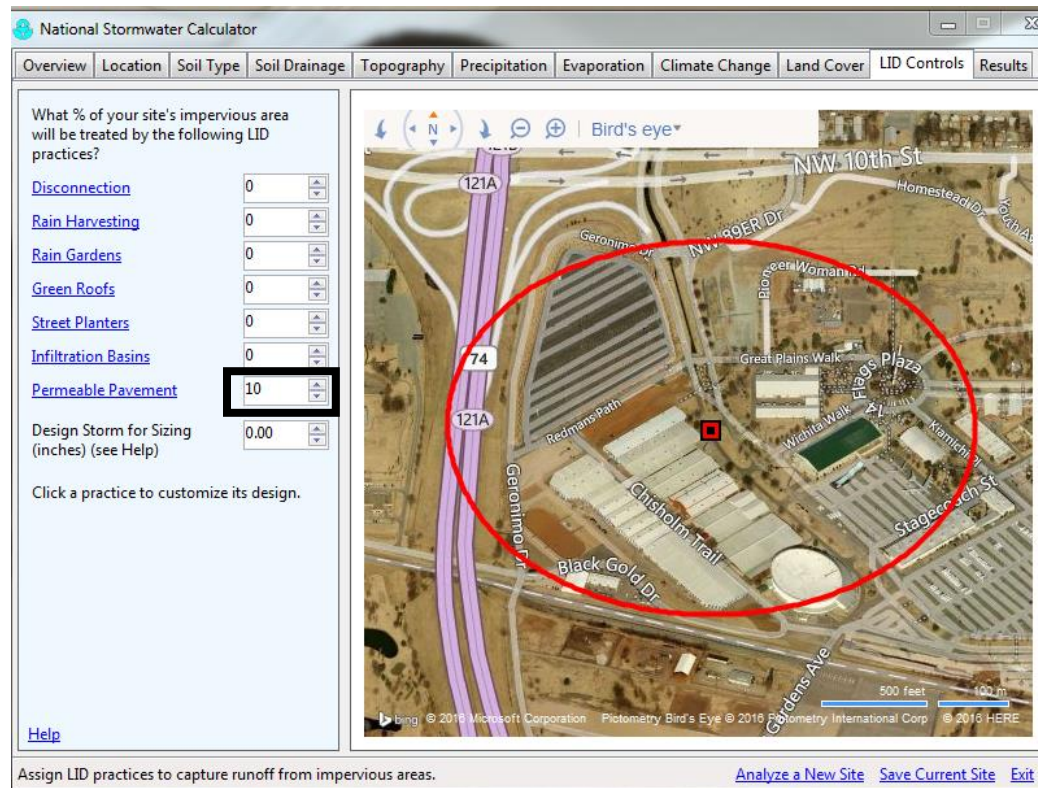
## Flexible constraints

- Implement a certain amount of LID for other purposes – aesthetics, education, ecosystem services



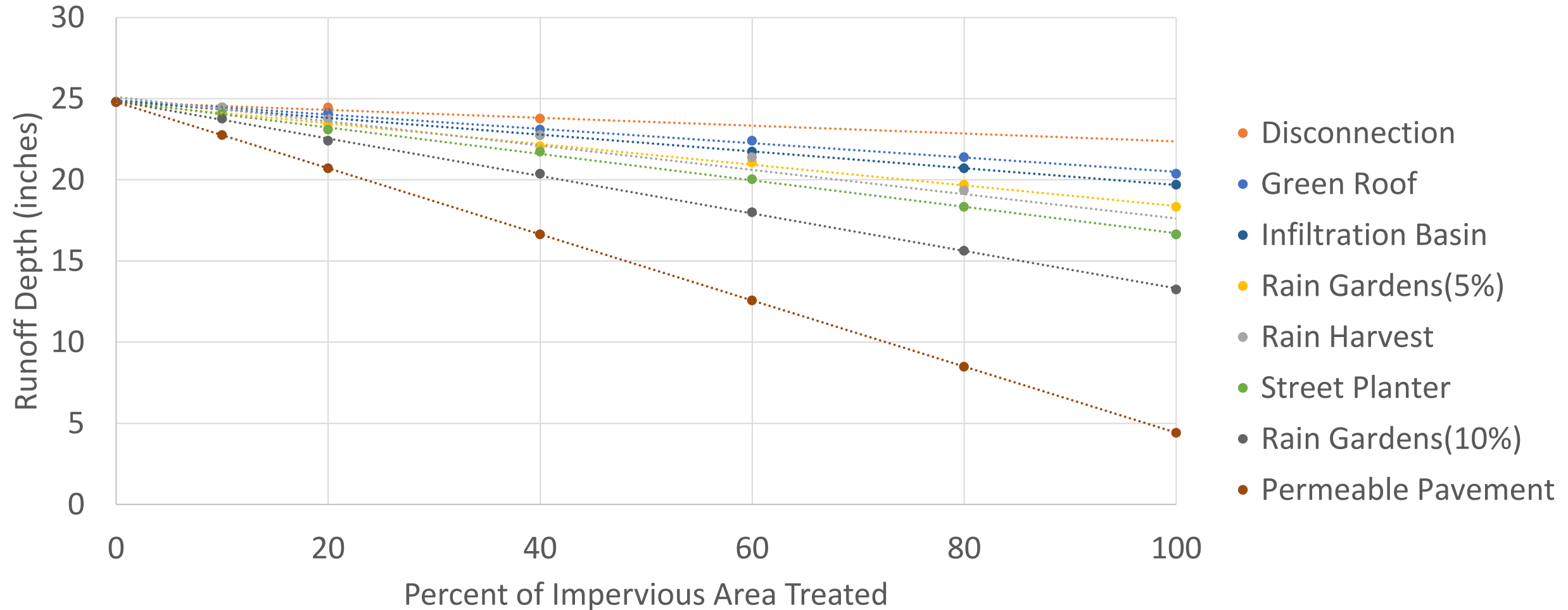
# Regression

- EPA Stormwater Calculator output for different percentages of impervious area treated by each singular LID type



# Regression (cont.)

Runoff Depth for Impervious Area Treated by Different LID Types



# Regression (cont.)

LID Type	Regression Equation
Disconnection	$D_{runoff} = -0.035(A) + 25.1$
Green Roof	$D_{runoff} = -0.047(A) + 25.1$
Rain Gardens (drainage area = 5% of treatment area)	$D_{runoff} = -0.069(A) + 25.1$
Rain Harvest	$D_{runoff} = -0.075(A) + 25.1$
Street Planter	$D_{runoff} = -0.085(A) + 25.1$
Rain Gardens (drainage area = 10% of treatment area)	$D_{runoff} = -0.12(A) + 25.1$
Permeable Pavement	$D_{runoff} = -0.21(A) + 25.1$

$D_{runoff}$  = Depth of runoff generated

$A$  = % Impervious area treated

# Runoff Calculation

- Calculate runoff with selected amount of impervious area treated

## Example

Treat 10% of impervious area with permeable asphalt

$$D_{runoff} = -0.21(10) + 25.1$$

$$D_{runoff} = 22.8 \text{ inches}$$

$$D_{reduced} = D_{current} - D_{runoff}$$

$$2.1 \text{ inches} = 25.1 \text{ inches} - 23 \text{ inches}$$

(8% reduction)

# Cost Calculation

- Calculate cost with selected amount of impervious area treated

## Example

Treat 10% of impervious area with permeable asphalt

$$Present\ Cost(\$ / ft^2) = Capital\ Cost(\$ / ft^2) + Maintenance\ Cost(\$ / ft^2) * \left( \frac{N}{1 + i} \right)$$

$$5.47(\$ / ft^2) = 1.5(\$ / ft^2) + 0.19(\$ / ft^2) * \left( \frac{20 years}{1.03} \right)$$

10% of impervious area = 8.3 acres

$$Total\ Present\ Value\ Cost(\$) = 5.47 \left( \$ / ft^2 \right) * 8.3 acres * \frac{43,560 ft^2}{1 acre}$$

Total Present Value Cost = \$3.3 million

# Minimization Functions

**Calculate runoff reduction minimization function:**

LID runoff depth to predevelopment runoff depth

$$\text{Runoff ratio} = \frac{\text{Runoff}_{LID}}{\text{Runoff}_{Pre}}$$

**Calculate cost minimization function:**

20-yr cost per gallon

$$\text{\$ per gallon} = \frac{(20\text{yr \$})}{\text{Vol}_{reduction}}$$

**Calculate multi-objective minimization function:**

Runoff reduction and cost per gallon

$$f_{min} = (\text{Runoff ratio}) \times (\text{\$ per gallon})$$

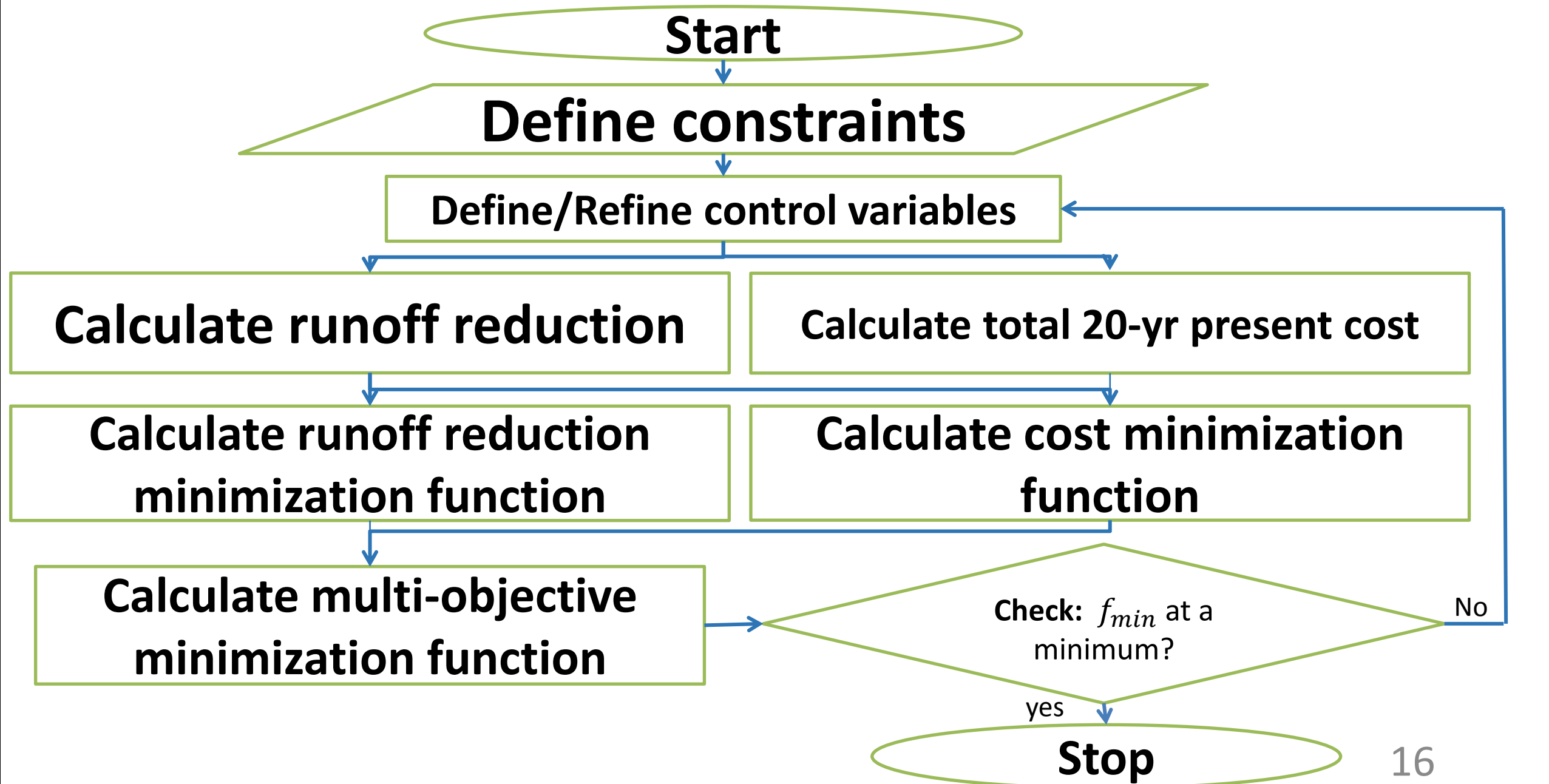
# Minimization Functions

- $Runoff\ ratio = \frac{Runoff_{LID}}{Runoff_{Pre}} = \frac{23\ inches}{11.7\ inches} = 1.97$

- $\$ per\ gallon = \frac{(20yr\ \$)}{Vol_{reduction}} = \$0.49$

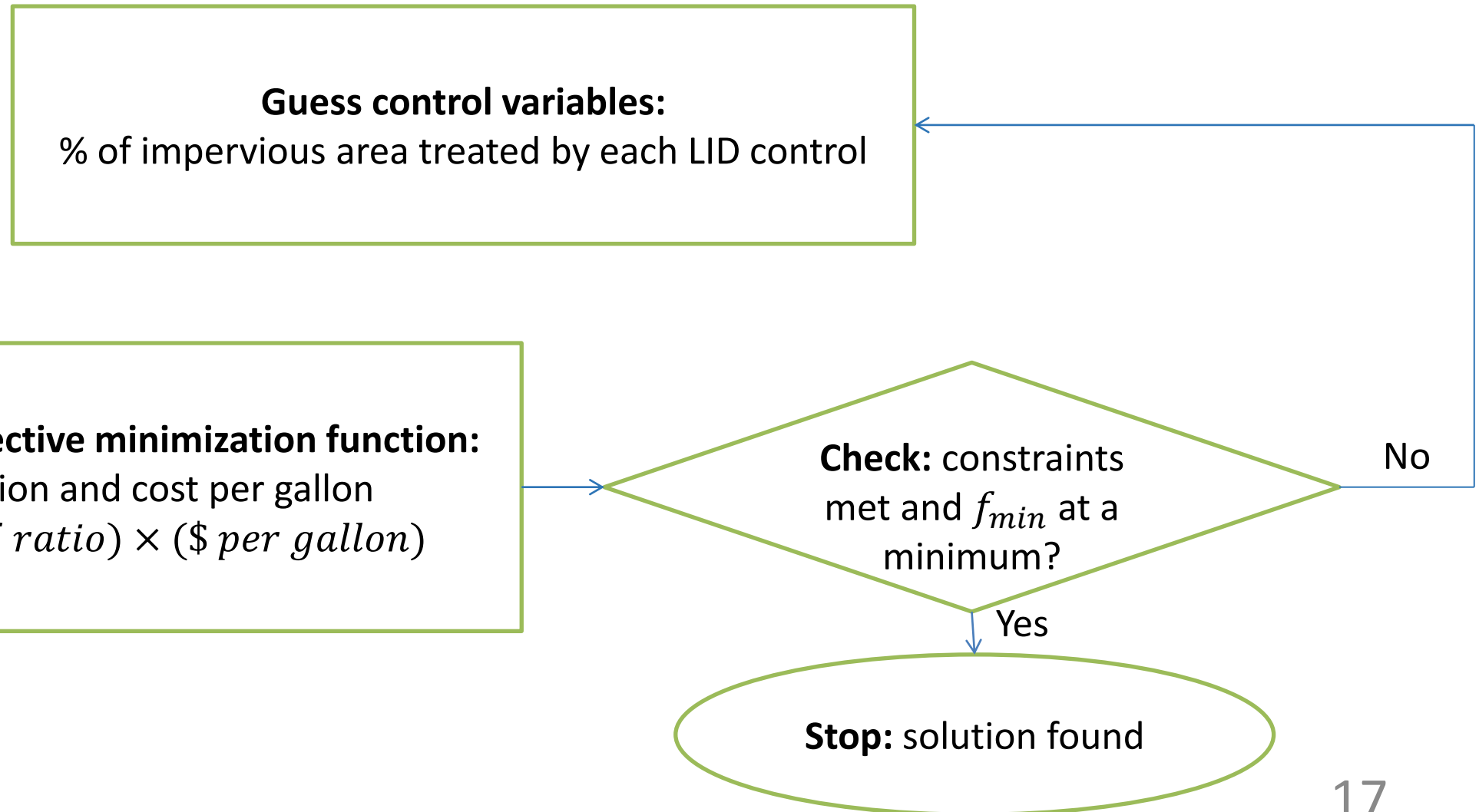
- $f_{min} = (Runoff\ ratio) \times (\$ per\ gallon) = 0.958$

# Back to the flow chart

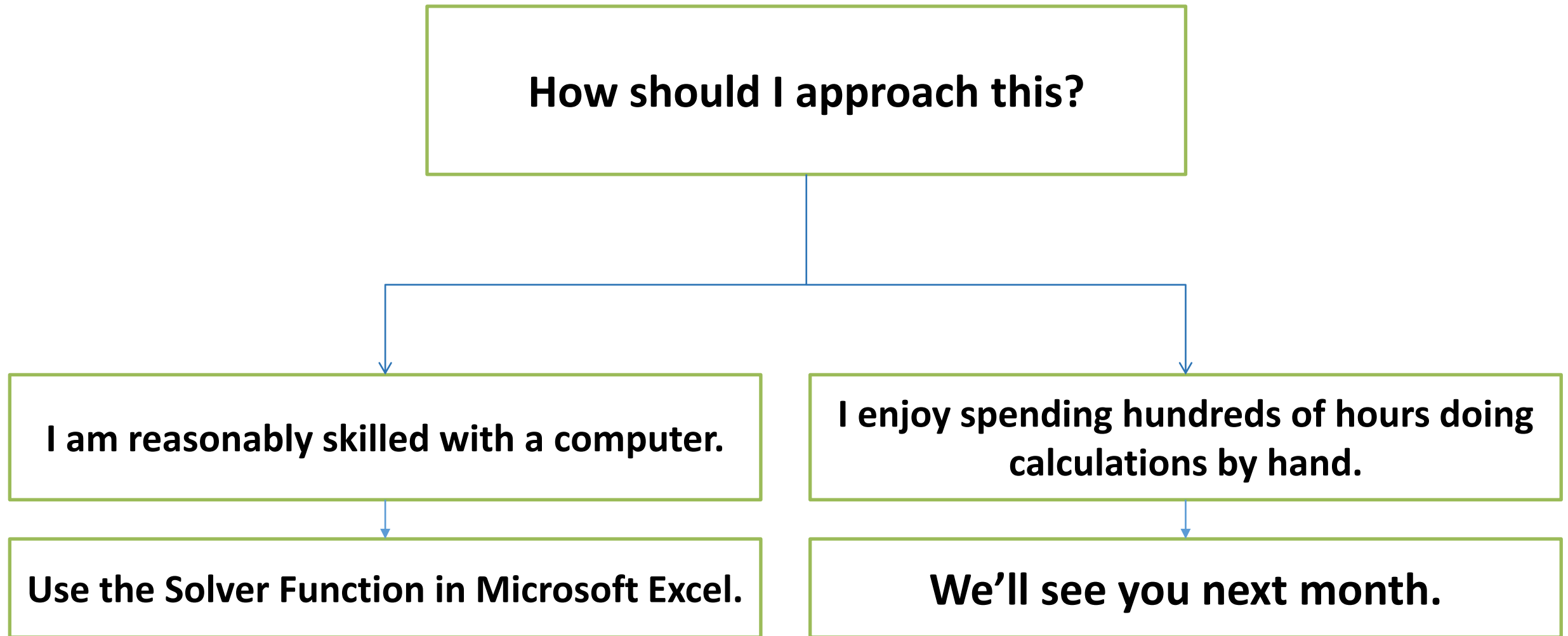




# Are we done?



# Minimization Function



# Microsoft Excel Solver

File → Options

The screenshot shows the Microsoft Excel application window titled 'Fairgrounds - Excel'. The 'File' tab is selected, and the 'Options' menu item is highlighted with a black box. The main content area displays the 'Info' section, which includes the following options:

- Protect Workbook**: Control what types of changes people can make to this workbook.
- Inspect Workbook**: Before publishing this file, be aware that it contains:
  - Document properties, author's name and absolute path
  - Links to other files
  - Hidden names
  - Content that people with disabilities are unable to read
- Versions**:
  - Today, 8:54 AM (autosave)
  - Today, 8:33 AM (autosave)
- Browser View Options**: Pick what users can see when this workbook is viewed on the Web.

The right sidebar displays the following sections:

- Properties**:
  - Size: 125KB
  - Title: Add a title
  - Tags: Add a tag
  - Categories: Add a category
- Related Dates**:
  - Last Modified: Today, 8:54 AM
  - Created: 9/26/2016 2:05 PM
  - Last Printed
- Related People**:
  - Author: McMaine, John
  - Add an author
  - Last Modified By: McMaine, John
- Related Documents**:
  - Open File Location
  - Edit Links to Files
  - Show All Properties

The Windows taskbar at the bottom shows the following icons: Start button, Internet Explorer, File Explorer, Microsoft Edge, Google Chrome, Microsoft Excel, Microsoft Word, and Microsoft PowerPoint. The system tray on the right shows the time as 9:05 AM on 9/30/2016.

# Microsoft Excel Solver

## Add-Ins

The screenshot shows the Microsoft Excel interface with the Solver function active in cell B4. The Solver function is set to minimize the cost per gallon (f\_min) based on the volume reduced and runoff of pre-treatment. The Solver Options dialog box is open, showing the Add-Ins tab. The Add-Ins list includes the Solver Add-in, which is highlighted. The Excel Options dialog box also shows the General options for working with Excel, including User Interface options, When creating new workbooks, and Personalize your copy of Microsoft Office.

**Solver function**

	A	B
1	<b>Solver function</b>	
2	% Volume Reduced	
3	% runoff of pre	
4	cost/gal	\$
5	f_min =	

**Solver Variable**

	A	B
12	<b>Solver Variable</b>	
13	Optimum %Imper	
14	Area Treated	
15	Rain Garden (5%)	0.0
16	Rain Garden (10%)	0.0
17	Bioretention	0.0
18	Green Roof ext	0.0
19	Green Roof int	0.0
20	Perm Asphalt	10.0
21	Perm Concrete	0.0
22	Perm Pavers	0.0
23	Infiltration Basin	0.0
24	Street Planters	0.0
25	Rain Harvesting	0.0
26	Sum	

**Excel Options - Add-Ins**

General options for working with Excel.

**User Interface options**

- ☒ Show Mini Toolbar on selection
- ☒ Show Quick Analysis options on selection
- ☒ Enable Live Preview
- ScreenTip style: Show feature descriptions in ScreenTips

**When creating new workbooks**

- Use this as the default font: Body Font
- Font size: 11
- Default view for new sheets: Normal View
- Include this many sheets: 1

**Personalize your copy of Microsoft Office**

- User name: McMaine, John
- ☐ Always use these values regardless of sign in to Office.
- Office Background: Circles and Stripes
- Office Theme: White

**Start up options**

- Choose the extensions you want Excel to open by default: Default Programs...
- ☒ Tell me if Microsoft Excel isn't the default program for viewing and editing spreadsheets.
- ☒ Show the Start screen when this application starts

**Additional Constraints**

	A	B
26	<b>Additional Constraints</b>	
27	Sum of Contributing	Solver Constraints (% of
28	Area Treated	total area)

**Regression**

	A	B
29	<b>Regression</b>	
30	Watershed Delineation	Stormwater Calc Results

**Stormwater Calc Results**

	A	B
31	<b>Stormwater Calc Results</b>	
32	Regression	Watershed Delineation

**Watershed Delineation**

	A	B
33	<b>Watershed Delineation</b>	
34	Stormwater Calc Results	Solver

**Solver**

	A	B
35	<b>Solver</b>	
36	Regression	Watershed Delineation

**Regression**

	A	B
37	<b>Regression</b>	
38	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
39	<b>Watershed Delineation</b>	
40	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
41	<b>Stormwater Calc Results</b>	
42	Regression	Watershed Delineation

**Regression**

	A	B
43	<b>Regression</b>	
44	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
45	<b>Watershed Delineation</b>	
46	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
47	<b>Stormwater Calc Results</b>	
48	Regression	Watershed Delineation

**Regression**

	A	B
49	<b>Regression</b>	
50	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
51	<b>Watershed Delineation</b>	
52	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
53	<b>Stormwater Calc Results</b>	
54	Regression	Watershed Delineation

**Regression**

	A	B
55	<b>Regression</b>	
56	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
57	<b>Watershed Delineation</b>	
58	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
59	<b>Stormwater Calc Results</b>	
60	Regression	Watershed Delineation

**Regression**

	A	B
61	<b>Regression</b>	
62	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
63	<b>Watershed Delineation</b>	
64	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
65	<b>Stormwater Calc Results</b>	
66	Regression	Watershed Delineation

**Regression**

	A	B
67	<b>Regression</b>	
68	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
69	<b>Watershed Delineation</b>	
70	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
71	<b>Stormwater Calc Results</b>	
72	Regression	Watershed Delineation

**Regression**

	A	B
73	<b>Regression</b>	
74	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
75	<b>Watershed Delineation</b>	
76	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
77	<b>Stormwater Calc Results</b>	
78	Regression	Watershed Delineation

**Regression**

	A	B
79	<b>Regression</b>	
80	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
81	<b>Watershed Delineation</b>	
82	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
83	<b>Stormwater Calc Results</b>	
84	Regression	Watershed Delineation

**Regression**

	A	B
85	<b>Regression</b>	
86	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
87	<b>Watershed Delineation</b>	
88	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
89	<b>Stormwater Calc Results</b>	
90	Regression	Watershed Delineation

**Regression**

	A	B
91	<b>Regression</b>	
92	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
93	<b>Watershed Delineation</b>	
94	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
95	<b>Stormwater Calc Results</b>	
96	Regression	Watershed Delineation

**Regression**

	A	B
97	<b>Regression</b>	
98	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
99	<b>Watershed Delineation</b>	
100	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
101	<b>Stormwater Calc Results</b>	
102	Regression	Watershed Delineation

**Regression**

	A	B
103	<b>Regression</b>	
104	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
105	<b>Watershed Delineation</b>	
106	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
107	<b>Stormwater Calc Results</b>	
108	Regression	Watershed Delineation

**Regression**

	A	B
109	<b>Regression</b>	
110	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
111	<b>Watershed Delineation</b>	
112	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
113	<b>Stormwater Calc Results</b>	
114	Regression	Watershed Delineation

**Regression**

	A	B
115	<b>Regression</b>	
116	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
117	<b>Watershed Delineation</b>	
118	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
119	<b>Stormwater Calc Results</b>	
120	Regression	Watershed Delineation

**Regression**

	A	B
121	<b>Regression</b>	
122	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
123	<b>Watershed Delineation</b>	
124	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
125	<b>Stormwater Calc Results</b>	
126	Regression	Watershed Delineation

**Regression**

	A	B
127	<b>Regression</b>	
128	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
129	<b>Watershed Delineation</b>	
130	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
131	<b>Stormwater Calc Results</b>	
132	Regression	Watershed Delineation

**Regression**

	A	B
133	<b>Regression</b>	
134	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
135	<b>Watershed Delineation</b>	
136	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
137	<b>Stormwater Calc Results</b>	
138	Regression	Watershed Delineation

**Regression**

	A	B
139	<b>Regression</b>	
140	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
141	<b>Watershed Delineation</b>	
142	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
143	<b>Stormwater Calc Results</b>	
144	Regression	Watershed Delineation

**Regression**

	A	B
145	<b>Regression</b>	
146	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
147	<b>Watershed Delineation</b>	
148	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
149	<b>Stormwater Calc Results</b>	
150	Regression	Watershed Delineation

**Regression**

	A	B
151	<b>Regression</b>	
152	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
153	<b>Watershed Delineation</b>	
154	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
155	<b>Stormwater Calc Results</b>	
156	Regression	Watershed Delineation

**Regression**

	A	B
157	<b>Regression</b>	
158	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
159	<b>Watershed Delineation</b>	
160	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
161	<b>Stormwater Calc Results</b>	
162	Regression	Watershed Delineation

**Regression**

	A	B
163	<b>Regression</b>	
164	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
165	<b>Watershed Delineation</b>	
166	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
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168	Regression	Watershed Delineation

**Regression**

	A	B
169	<b>Regression</b>	
170	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
171	<b>Watershed Delineation</b>	
172	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
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**Regression**

	A	B
175	<b>Regression</b>	
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**Watershed Delineation**

	A	B
177	<b>Watershed Delineation</b>	
178	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
179	<b>Stormwater Calc Results</b>	
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**Regression**

	A	B
181	<b>Regression</b>	
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**Watershed Delineation**

	A	B
183	<b>Watershed Delineation</b>	
184	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
185	<b>Stormwater Calc Results</b>	
186	Regression	Watershed Delineation

**Regression**

	A	B
187	<b>Regression</b>	
188	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
189	<b>Watershed Delineation</b>	
190	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
191	<b>Stormwater Calc Results</b>	
192	Regression	Watershed Delineation

**Regression**

	A	B
193	<b>Regression</b>	
194	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
195	<b>Watershed Delineation</b>	
196	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
197	<b>Stormwater Calc Results</b>	
198	Regression	Watershed Delineation

**Regression**

	A	B
199	<b>Regression</b>	
200	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
201	<b>Watershed Delineation</b>	
202	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
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204	Regression	Watershed Delineation

**Regression**

	A	B
205	<b>Regression</b>	
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**Watershed Delineation**

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207	<b>Watershed Delineation</b>	
208	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
209	<b>Stormwater Calc Results</b>	
210	Regression	Watershed Delineation

**Regression**

	A	B
211	<b>Regression</b>	
212	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
213	<b>Watershed Delineation</b>	
214	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
215	<b>Stormwater Calc Results</b>	
216	Regression	Watershed Delineation

**Regression**

	A	B
217	<b>Regression</b>	
218	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
219	<b>Watershed Delineation</b>	
220	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
221	<b>Stormwater Calc Results</b>	
222	Regression	Watershed Delineation

**Regression**

	A	B
223	<b>Regression</b>	
224	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
225	<b>Watershed Delineation</b>	
226	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
227	<b>Stormwater Calc Results</b>	
228	Regression	Watershed Delineation

**Regression**

	A	B
229	<b>Regression</b>	
230	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
231	<b>Watershed Delineation</b>	
232	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
233	<b>Stormwater Calc Results</b>	
234	Regression	Watershed Delineation

**Regression**

	A	B
235	<b>Regression</b>	
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**Watershed Delineation**

	A	B
237	<b>Watershed Delineation</b>	
238	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
239	<b>Stormwater Calc Results</b>	
240	Regression	Watershed Delineation

**Regression**

	A	B
241	<b>Regression</b>	
242	Watershed Delineation	Stormwater Calc Results

**Watershed Delineation**

	A	B
243	<b>Watershed Delineation</b>	
244	Stormwater Calc Results	Solver

**Stormwater Calc Results**

	A	B
245	<b>Stormwater Calc Results</b>	
246		

# Microsoft Excel Solver

## Solver Add-in

The screenshot displays the Microsoft Excel interface with the 'Add-Ins' dialog box open. The dialog box lists available add-ins, and 'Solver Add-in' is selected. The background spreadsheet is a complex model for stormwater management, featuring various input variables, constraints, and calculated results.

**Spreadsheet Data:**

Component	Area (Acre)	% of total	% Imp Area
Streets/Parking Lots	47	39%	56%
Roofs	31	26%	38%
Sidewalks/Other			
Total Impervious			
Pervious Area			
Total			

Solver function													
% Volume Reduced	8%												
% runoff of pre	1.966												
cost/gal	\$ 0.49												
f_min =	0.958												

Solver Inputs													
Solver Variables	Solver Constraints (% of impervious area)												
Optimum %Impervious Area Treated	Lower Limit	Upper Limit											
Rain Garden (5%)	0.0	0.0	100	Rain Garden (5%)	1.5								
Rain Garden (10%)	0.0	0.0	100	Rain Garden (10%)	1.5								
Bioretention	0.0	0.0	100	Bioretention	1.5								
Green Roof ext	0.0	0.0	38	Green Roof ext	-								
Green Roof int	0.0	0.0	38	Green Roof int	-								
Perm Asphalt	10.0	0.0	56	Perm Asphalt	2								
Perm Concrete	0.0	0.0	62	Perm Concrete	2								
Perm Pavers	0.0	0.0	62	Perm Pavers	2								
Infiltration Basin	0.0	0.0	100	Infiltration Basin	0.5								
Street Planters	0.0	0.0	62	Street Planters	2.5								
Rain Harvesting	0.0	0.0	38	Rain Harvesting	-								
Sum	10												

Annual Maintenance	20 yr Present Cost	% Capture Ratio	Total 20-yr Present Cost	Regression Equation	Runoff
\$(/ft²*year)	\$(/ft²)		(\$)	(%area versus runoff)	
0.34	12.2	0.05	\$ -	25.1	
0.34	12.2	0.1	\$ -	25.1	
0.34	27.2	0.05	\$ -	25.1	
1.5	39.1	1	\$ -	25.1	
1.5	54.1	1	\$ -	25.1	
0.19	9.2	1	\$ 3,332,002	23.0	
0.16	14.1	1	\$ -	25.1	
0.04	14.7	1	\$ -	25.1	
0.72	34.2	0.05	\$ -	25.1	
0.8	17.8	0.05	\$ -	25.1	
0.04	1.7	1	\$ -	25.1	
			\$ 3,332,002		

The bottom of the spreadsheet shows tabs for 'Regression', 'Watershed Delineation', 'Stormwater Calc Results', and 'Solver'. The 'Solver' tab is currently active.

# Microsoft Excel Solver

- Set Objective
- By Changing Variable Cells

The screenshot displays the Microsoft Excel Solver interface. The Solver Parameters dialog box is open, showing the following settings:

- Set Objective:** \$B\$5
- To:** ☒ Max ☐ Min ☐ Value Of: 0
- By Changing Variable Cells:** \$B\$14:\$B\$24
- Subject to the Constraints:** (Empty list)
- ☒ Make Unconstrained Variables Non-Negative
- Select a Solving Method:** GRG Nonlinear
- Solving Method:** Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

The background spreadsheet shows the following data:

Solver function			
% Volume Reduced	8%		
% runoff of pre	1.966		
f_min =	0.958		

Solver Variables			
	Optimum %Impervious Area Treated	Lower Limit	Upper Limit
Rain Garden (5%)	0.0	0.0	100
Rain Garden (10%)	0.0	0.0	100
Bioretention	0.0	0.0	100
Green Roof ext	0.0	0.0	38
Green Roof int	0.0	0.0	38
Perm Asphalt	10.0	0.0	56
Perm Concrete	0.0	0.0	62
Perm Pavers	0.0	0.0	62
Infiltration Basin	0.0	0.0	100
Street Planters	0.0	0.0	62
Rain Harvesting	0.0	0.0	38
Sum	10		

Additional Constraints			
	Sum of Contributing	Solver Constraints (% of	

Other Costs			

The Solver Parameters dialog box is overlaid on the spreadsheet, and the Solver button is highlighted in the top right corner of the ribbon.

# Setting Constraints

- What can be treated by each LID type?
  - Green roof and rain harvesting can only treat roof
  - Permeable asphalt can only treat streets/parking lots
  - Permeable concrete, permeable pavers, and street planters can treat streets/parking lots and sidewalks/other
  - Raingardens, bioretention, and infiltration basins can treat anything
- How much space is available for each LID type?
  - Rain gardens, bioretention, and infiltration basins compete for green space
  - Permeable asphalt, permeable concrete, permeable pavers, and street planters compete for pavement area
  - Green roofs and rain harvesting compete for roof area

# Setting Constraints

- “Subject to the Constraints”
- Add

The screenshot displays the Microsoft Excel interface with the Solver Parameters dialog box open. The background spreadsheet, titled 'Fairgrounds - Excel', contains data for a stormwater management model. The Solver Parameters dialog is configured as follows:

- Set Objective:** \$B\$5
- To:** ☒ Max ☐ Min ☐ Value Of: 0
- By Changing Variable Cells:** \$B\$14:\$B\$24
- Subject to the Constraints:** A list of constraints including \$B\$14 <= \$D\$14, \$B\$14 >= \$C\$14, \$B\$15 <= \$D\$15, \$B\$15 >= \$C\$15, \$B\$16 <= \$D\$16, \$B\$16 >= \$C\$16, \$B\$17 <= \$D\$17, \$B\$17 >= \$C\$17, \$B\$18 <= \$D\$18, \$B\$18 >= \$C\$18, \$B\$19 <= \$D\$19, \$B\$19 >= \$C\$19, and \$B\$2 >= 60.
- ☒ Make Unconstrained Variables Non-Negative
- Select a Solving Method:** GRG Nonlinear
- Solving Method:** Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

The spreadsheet data includes a table of component areas (Streets/Parking Lots, Roofs, Sidewalks/Other, Total Impervious, Pervious Area, Total) and a table of solver inputs (Rain Garden, Bioretention, Green Roof, Perm Asphalt, Perm Concrete, Perm Pavers, Infiltration Basin, Street Planters, Rain Harvesting) with columns for Area (Acre), % Impervious, and Excavation Depth (ft). The Solver Parameters dialog box is positioned over the spreadsheet, showing the constraints and solving method settings.



# Optional Constraints

- Aesthetic or educational – want at least one green roof or rain garden
- Cost per gallon – want cost per gallon below \$0.50/gallon
- Want LID runoff to equal predevelopment runoff -

$$\frac{Runoff_{LID}}{Runoff_{Pre}} = \frac{11.7 \text{ inches}}{11.7 \text{ inches}} = 1$$

- Want to reduce runoff volume by > 60%

$$\frac{Runoff_{LID}}{Runoff_{Current}} = \frac{10 \text{ inches}}{25.1 \text{ inches}} = 0.6$$

# Future Optimizations

- Additional optimizations – water quality, peak flow reduction, ecosystem services
- Weighted combinations - set water quality more important than cost...
- Range of parameters set by user