🌊 A* FLOOD ROUTING SYSTEM

Smart Navigation with Real-Time Flood Avoidance

📍 MALOLOS CITY, BULACAN, PHILIPPINES

Report Generated: December 01, 2025 at 04:38 AM

ROUTE INFORMATION

🟢 **START: Malolos City Hall**

F. Llamas Street, Brgy. Sto. Niño, Malolos City

🔴 **END: Bulacan State University (Main Campus)**

MacArthur Highway, Brgy. Guinhawa, Malolos City

SYSTEM FEATURES:
✓ Real OpenStreetMap road data   ✓ Respects one-way streets & road closures
✓ A* optimal pathfinding   ✓ Real-time flood detection sensors
✓ Traffic-aware routing   ✓ Busy street identification
✓ Smart rerouting algorithm   ✓ Turn-by-turn directions with road names

⬡ HOW NODES ARE ACQUIRED

Understanding the Road Network Data Source

⬡ DATA SOURCE: OpenStreetMap (OSM)

• OpenStreetMap is a collaborative, free geographic database

• Data is contributed by volunteers worldwide and regularly updated

• Accessed via Overpass API using OSMnx Python library

⬡ NODE ACQUISITION PROCESS:

1️⃣ Query OSM Overpass API with city boundary (Malolos, Bulacan)

2️⃣ Filter for drivable roads only (network_type="drive")

3️⃣ Extract road intersections as NODES (vertices)

4️⃣ Extract road segments as EDGES (connections between nodes)

5️⃣ Simplify network topology (remove redundant nodes)

6️⃣ Add speed limits and travel time estimates per road type

7️⃣ Apply traffic multipliers based on road classification

⬡ NETWORK STATISTICS

Total Nodes: 4,356   Total Edges: 11,476

One-way Roads: 76   Two-way Roads: 11,400

TRAFFIC ESTIMATION & ROAD CLASSIFICATION

TRAFFIC MULTIPLIERS BY ROAD TYPE:

| Road Type	Traffic Factor	Description
Primary Road	1.5x	Main roads - heavy traffic (e.g., MacArthur Highway)
Secondary Road	1.3x	Secondary roads - moderate traffic
Tertiary Road	1.2x	Local roads - light to moderate traffic
Residential	1.1x	Residential streets - light traffic
Busy Street Bonus	+30%	Additional delay for known busy streets

KNOWN BUSY STREETS IN MALOLOS

- MacArthur Highway
- Paseo del Congreso
- F. Llamas Street
- Plaridel Bypass Road
- Cagayan Valley Road
- Governor F. Halili Avenue

ACTIVE ROAD CLOSURES:

CLOSED - Barasoain Street Section   Reason: Road Construction
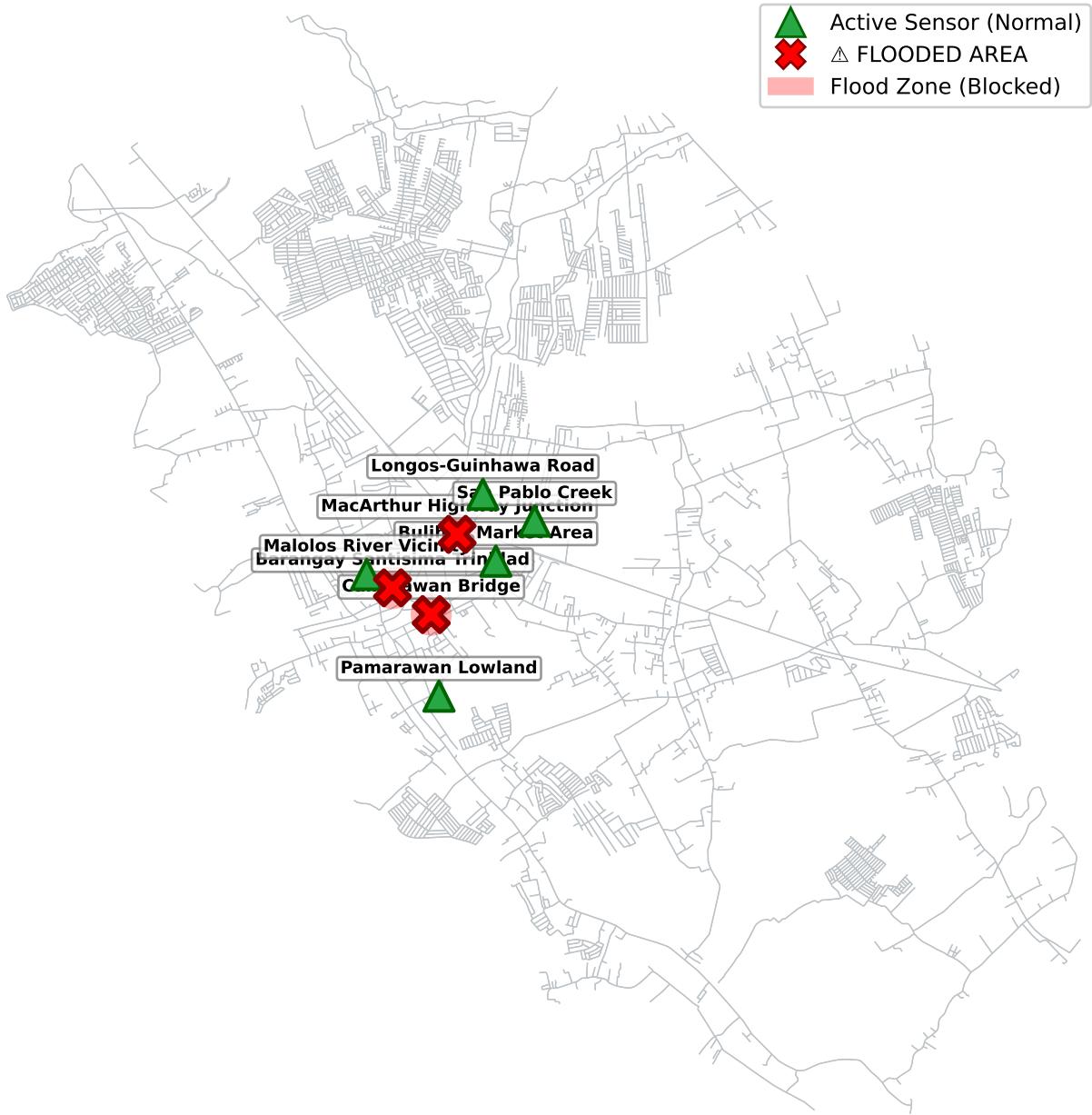
CLOSED - Near Public Market   Reason: Utility Maintenance

FLOOD SENSOR NETWORK - Malolos City, Bulacan
(Strategic Monitoring Points)

Legend:
- ▲ Active Sensor (Normal)
- ✖ ⚠ FLOODED AREA
- Flood Zone (Blocked)

Labels on map:
- Longos-Guinhawa Road
- San Pablo Creek
- MacArthur Highway Junction
- Bulihan Market Area
- Malolos River Vicinity
- barangay Santisima Trinidad
- Caliawan Bridge
- Pamarawan Lowland

🌊 FLOOD SENSOR STATUS REPORT

Real-time monitoring of strategic flood-prone locations

ID	SENSOR LOCATION	COORDINATES	STATUS
00	Barangay Santisima Trinidad	(14.8470°N, 120.8120°E)	🔴 **FLOODED**
01	MacArthur Highway Junction	(14.8510°N, 120.8170°E)	🔴 **FLOODED**
02	Bulihan Market Area	(14.8490°N, 120.8200°E)	🟢 **Normal**
03	Pamarawan Lowland	(14.8389°N, 120.8156°E)	🟢 **Normal**
04	San Pablo Creek	(14.8520°N, 120.8230°E)	🟢 **Normal**
05	Caliligawan Bridge	(14.8450°N, 120.8150°E)	🔴 **FLOODED**
06	Longos-Guinhawa Road	(14.8540°N, 120.8190°E)	🟢 **Normal**
07	Malolos River Vicinity	(14.8480°N, 120.8100°E)	🟢 **Normal**
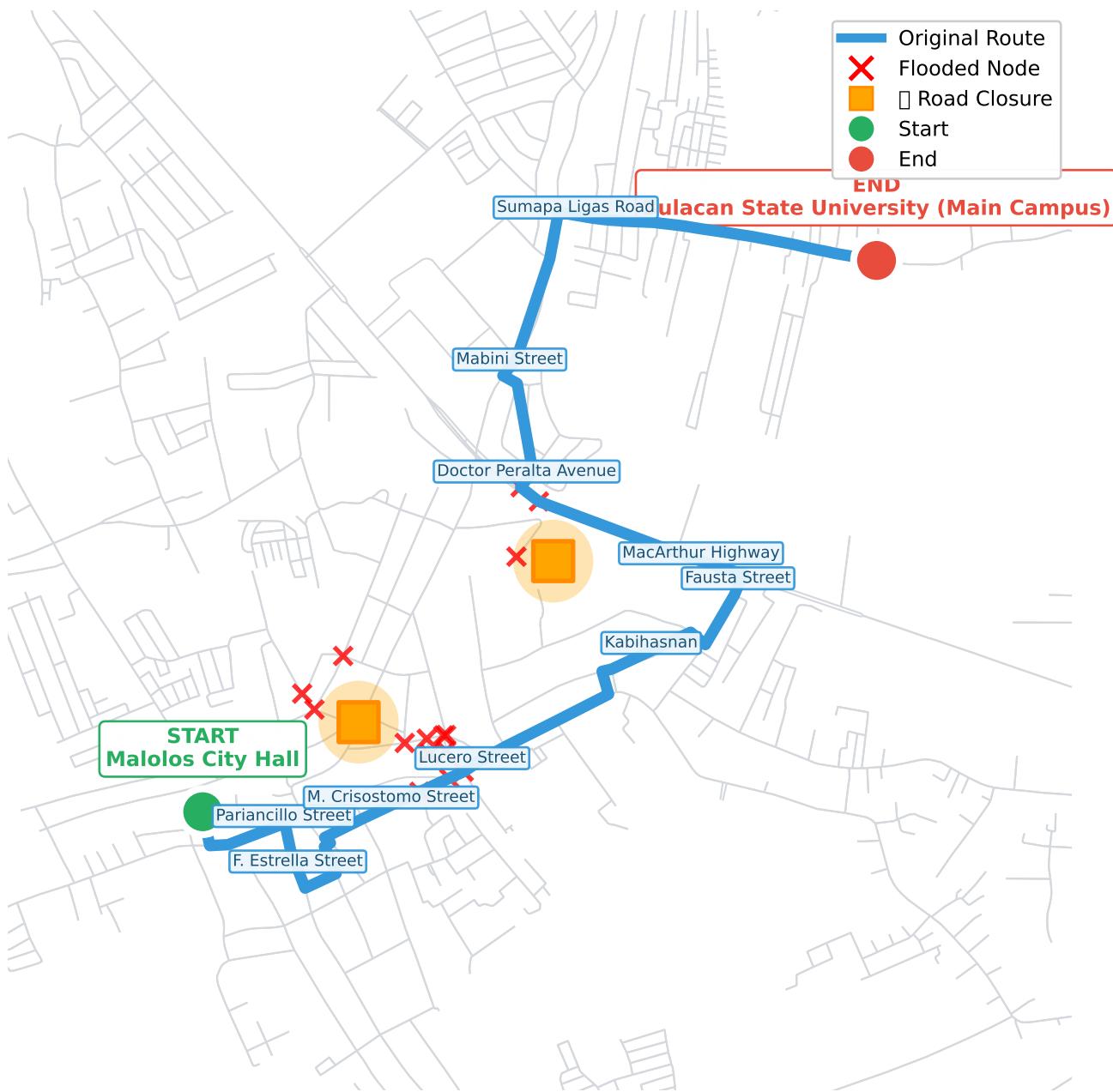
⚠ FLOOD ALERT SUMMARY

Active Sensors: 5 | **Flooded Areas: 3**

ORIGINAL ROUTE (Zoomed View)
Malolos City Hall → Bulacan State University (Main Campus)

Legend:
- Original Route
- ✕ Flooded Node
- 🟧 Road Closure
- 🟢 Start
- 🔴 End

END
Bulacan State University (Main Campus)

Sumapa Ligas Road

Mabini Street

Doctor Peralta Avenue

MacArthur Highway

Fausta Street

Kabihasnan

START
Malolos City Hall

Lucero Street

M. Crisostomo Street

Pariancillo Street

F. Estrella Street
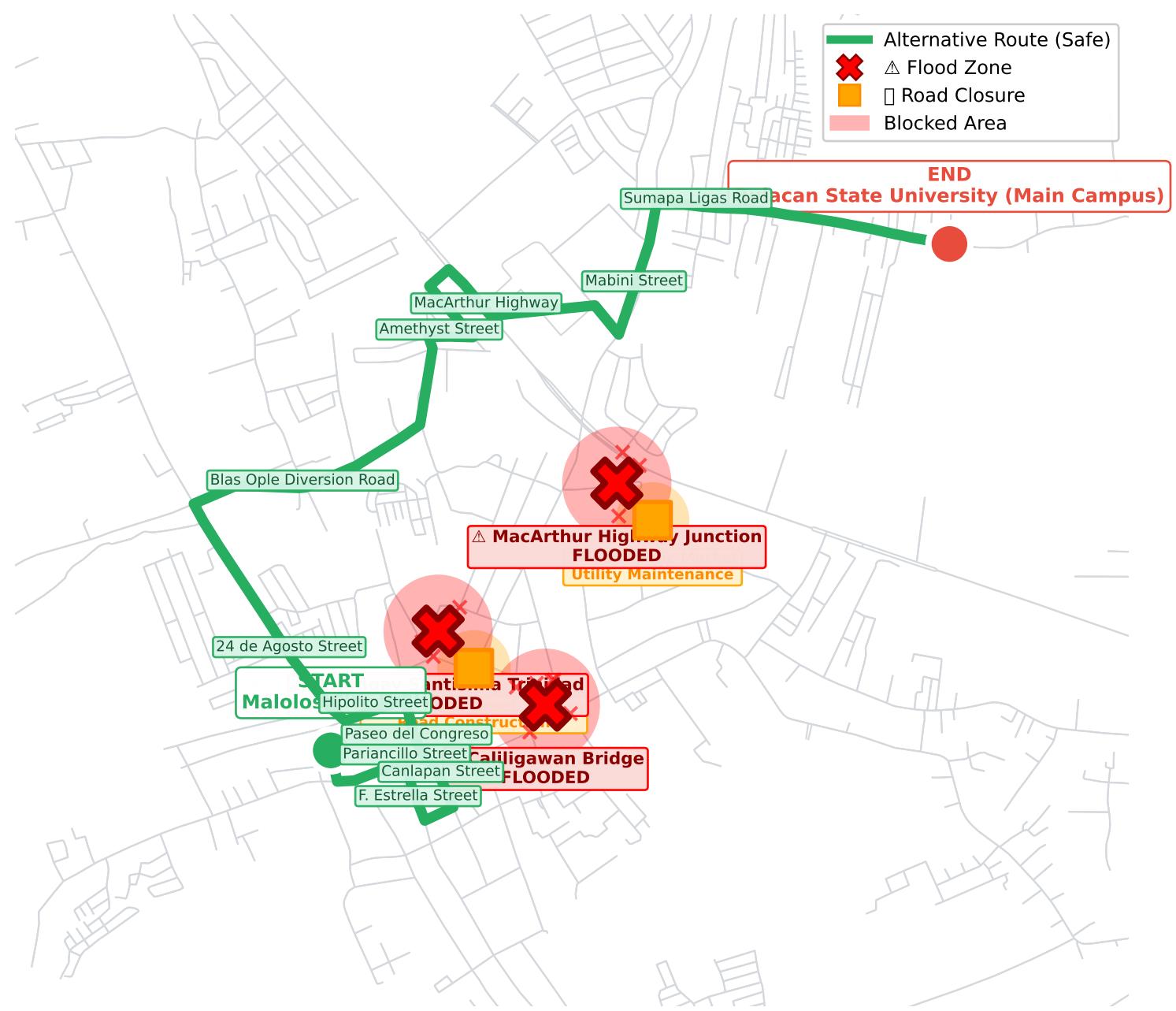
📏 Distance: 4.64 km | ⏱ Base Time: 8.0 min | 🚦 With Traffic: 9.8 min
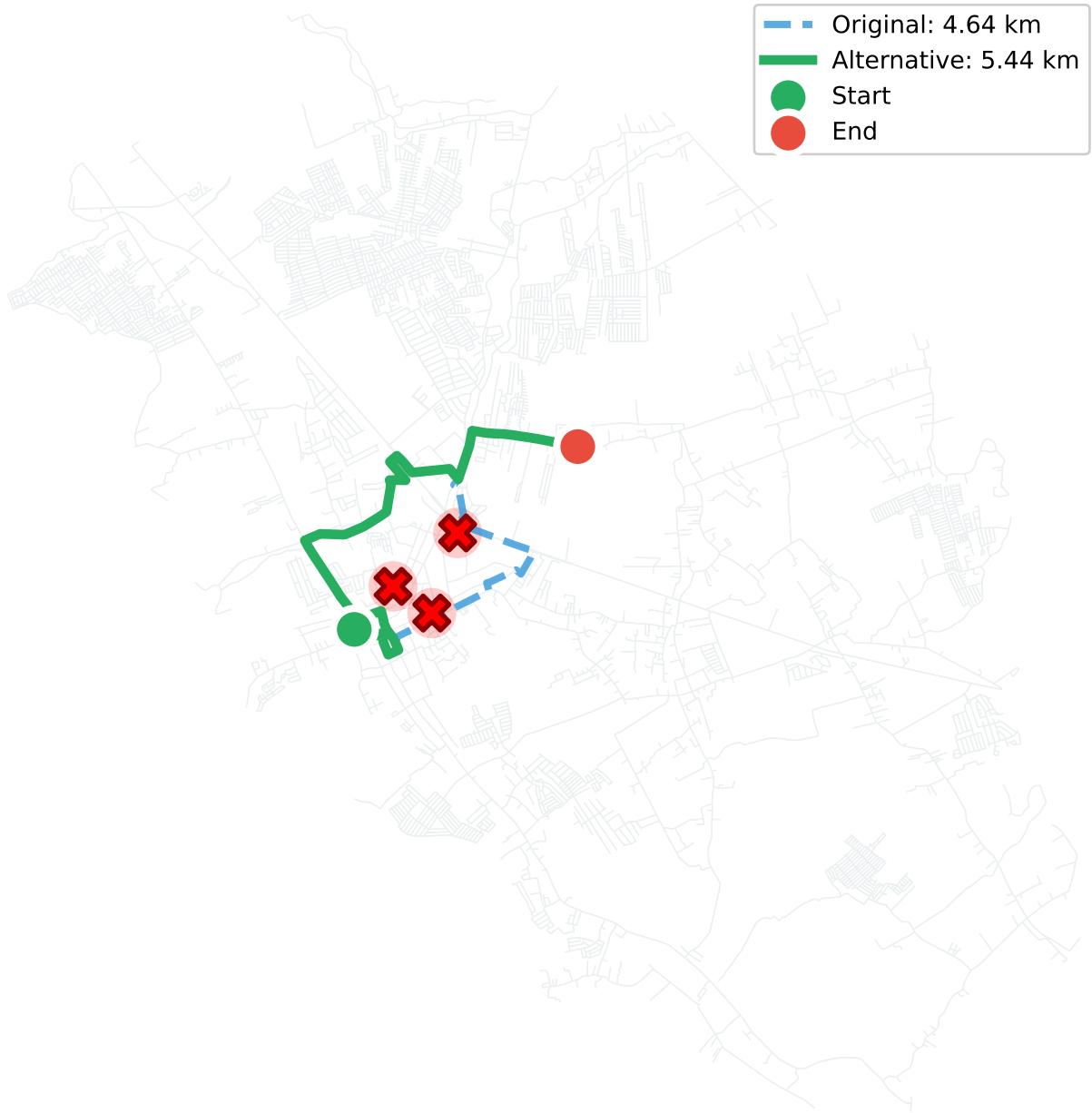
ALTERNATIVE ROUTE - FLOOD-FREE PATH (Zoomed View)
Malolos City Hall → Bulacan State University (Main Campus)

Legend:
- Alternative Route (Safe)
- ⚠ Flood Zone
- 🚧 Road Closure
- Blocked Area

Sumapa Ligas Road

END
Bulacan State University (Main Campus)

Mabini Street

MacArthur Highway

Amethyst Street

Blas Ople Diversion Road

⚠ MacArthur Highway Junction
FLOODED
Utility Maintenance

24 de Agosto Street

START
Malolos

Santisima Trinidad
FLOODED
Road Construction

Hipolito Street

Paseo del Congreso

Pariancillo Street

Canlapan Street

F. Estrella Street

Caliligawan Bridge
FLOODED

🚗 Distance: 5.44 km | ⏱ Base Time: 7.7 min | 🚦 With Traffic: 9.8 min

ROUTE COMPARISON: Original vs Alternative
(Side-by-Side Analysis)

Original: 4.64 km
Alternative: 5.44 km
Start
End

🧭 TURN-BY-TURN DIRECTIONS

✅ RECOMMENDED ROUTE (Flood-Free):

1.	Start on Unnamed Road	98 m ↔
2.	Turn right Pariancillo Street	218 m →
3.	Turn left F. Estrella Street	189 m →
4.	Turn left T. Alonzo Street	95 m →
5.	Continue straight Canlapan Street	181 m →
6.	Continue straight Paseo del Congreso	89 m ↔
7.	Turn left P. Burgos Street	93 m ↔
8.	Turn right Hipolito Street	192 m ↔
9.	Turn right 24 de Agosto Street	800 m ↔
10.	Turn right Blas Ople Diversion Road	1.0 km ↔
11.	Make a sharp left Amethyst Street	134 m ↔
12.	Turn right Diamond Street	202 m ↔

🛣 ROADS ON ALTERNATIVE ROUTE:
Pariancillo Street, F. Estrella Street, T. Alonzo Street, Canlapan Street, Paseo del Congreso, P. Burgos Street, Hipolito Street, 24 de Agosto Street, Blas Ople Diversion Road, Amethyst Street

⚠ ORIGINAL ROUTE (May Pass Through Flood):

1.	Start on Unnamed Road	98 m
2.	Turn right Pariancillo Street	218 m
3.	Turn left F. Estrella Street	189 m
4.	Turn left T. Alonzo Street	95 m
5.	Turn right Canlapan Street	81 m
6.	Turn left Unnamed Road	19 m
7.	Turn right Pagsibigan Street	22 m
8.	Continue straight M. Crisostomo Street	381 m

🛣 ROADS ON ORIGINAL ROUTE:
Pariancillo Street, F. Estrella Street, T. Alonzo Street, Canlapan Street, Pagsibigan Street, M. Crisostomo Street, Lucero Street, Kabihasnan Street, Kabihasnan, Paraluman Street

🗺 ROUTE ANALYSIS SUMMARY

🚗 ORIGINAL ROUTE

Distance: 4.64 km

Travel Time: 8.0 min

Nodes: 57

⚠ BLOCKED BY FLOOD

🛡 ALTERNATIVE ROUTE

Distance: 5.44 km

Travel Time: 7.7 min

Nodes: 65

✅ SAFE & RECOMMENDED

📊 ROUTE DIFFERENCE

Distance: +0.80 km (+17.3%)   Time: -0.2 minutes

💡 RECOMMENDATION

Take the ALTERNATIVE ROUTE to safely avoid all flood-affected areas.

⬚ A* ALGORITHM TECHNICAL DETAILS

THE A* PATHFINDING ALGORITHM

A* finds the shortest path using the formula: $f(n) = g(n) + h(n)$

Where:
- $f(n)$ = Total estimated cost of path through node n
- $g(n)$ = Actual cost from start to node n
- $h(n)$ = Heuristic estimate from n to goal

IMPLEMENTATION FEATURES:

1. REAL ROAD NETWORK DATA
   - Source: OpenStreetMap (© OpenStreetMap contributors)
   - Respects one-way streets and turn restrictions
   - Includes all road types: highways, primary, secondary, residential

2. HEURISTIC FUNCTION
   - Uses Haversine formula for great-circle distance
   - Admissible heuristic (never overestimates)
   - Guarantees optimal path finding

3. FLOOD AVOIDANCE MECHANISM
   - Sensors detect flooding at strategic locations
   - Nodes within flood radius are marked as impassable
   - A* excludes flooded nodes from pathfinding
   - Real-time rerouting when floods detected

4. TRAVEL TIME ESTIMATION
   - Based on road type and speed limits
   - Considers road length and conditions
   - Factors in traffic characteristics

DATA SOURCES & REFERENCES:
   - Road Network: OpenStreetMap via OSMnx library
   - Coordinate System: WGS84 (EPSG:4326)
   - Flood Sensors: Simulated at known flood-prone areas