# 1.0 Summary

| | |
|---|---|
| **House Type** | Wood frame house with concrete base |
| **Year of Construction** | 2012 |
| **Floor Area** | Upper Floor – 94.67 $m^2$<br>Main Floor – 95.23 $m^2$<br>Lower Floor – 95.23 $m^2$ |
| **Location** | Kitsilano, Vancouver, B.C. |
| **Soil Type** | C |
| **Liquefaction Potential** | Very low |
| **Retrofit Priority Rank** | H3 |
| **Seismic Deficiencies** | 1. Upper floor E-W exterior LDRS needs improvement<br>2. Main floor N-S interior LDRS needs improvement<br>3. Main floor E-W exterior LDRS needs improvement |
| **Life-Safety Retrofit Features** | 1. Upper floor E-W exterior LDRS retrofit:<br>• Upgrade the frame by providing adequate nail end distance and better detailing<br>2. Main floor N-S interior LDRS retrofit:<br>• Upgrade the frame by providing adequate nail end distance and better detailing<br>3. Main floor E-W exterior LDRS retrofit:<br>• Upgrade the frame by providing adequate nail end distance and better detailing |
| **Retrofit Cost Estimates** | $23,028<br>$81 /$m^2$ |

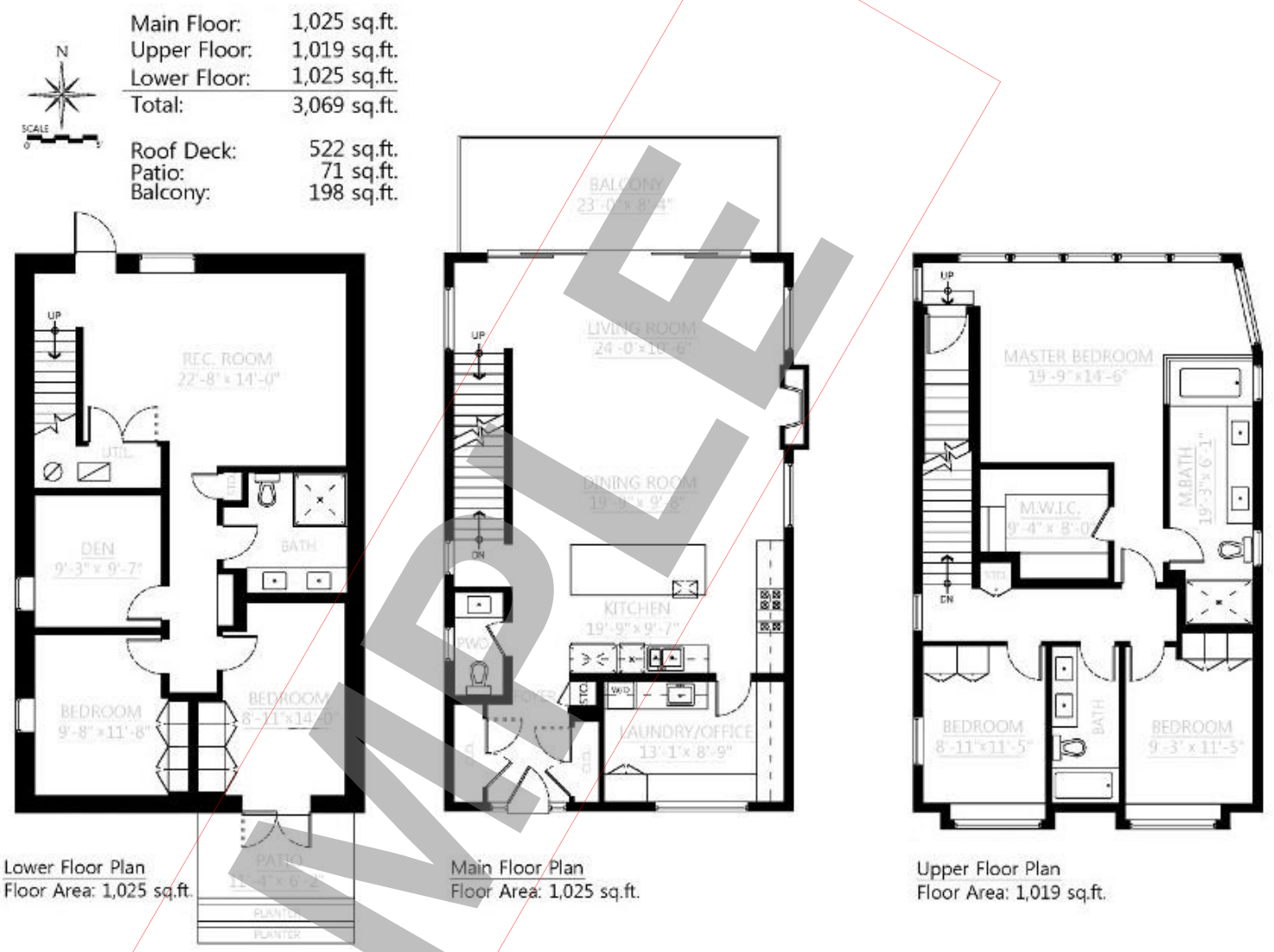


*Figure 1: Architectural drawing of the house*

# 2.0 Assessment Report

## 2.1 Vertical Load-Bearing Supports (VLS)

| | |
|---|---|
| **VLS Type** | Timber platform construction |
| **VLS Design Drift Limit** | 6.0% |
| **Supports Description** | The floor boards and joists, which act as a platform, are fastened over beams supporting the structure. The structural walls transfer the load from the roof and ceiling to the floor and the foundation. The perimeter of the house is supported by concrete walls. |

## 2.2 Lateral Demand Resisting Systems (LDRSs)

### 2.2.1 Upper Floor LDRS

| Shaking Dir. | Location | Prototype No. | Description | Max. DDL | Capacity |
|---|---|---|---|---|---|
| N-S | Exterior | W-1 | Blocked shearwall | 3.0% | 17.82% Ws |
| | Interior | W-1 | Blocked shearwall | 3.0% | 12.82% Ws |
| E-W | Exterior | W-1 | Blocked shearwall | 3.0% | 6.77% Ws |

**Comments**

- All walls are assumed to have blocking as the structure was constructed pretty recently
- All walls are assumed to be properly connected to the diaphragms
- Ws is the cumulative seismic weight of the structure (228.1 kN), which includes the weight of walls, roof, and snow
- Although there is no E-W LDRS in the interior (the existing E-W walls are not part of the LDRS), the exterior E-W LDRS is deemed to be able to handle the demand in the E-W direction

### 2.2.2 Main Floor LDRS

| Shaking Dir. | Location | Prototype No. | Description | Max. DDL | Capacity |
|---|---|---|---|---|---|
| N-S | Exterior | W-1 | Blocked shearwall | 3.0% | 9.01% Ws |
| | Interior | W-1 | Blocked shearwall | 3.0% | 3.11% Ws |
| E-W | Exterior | W-1 | Blocked shearwall | 3.0% | 3.64% Ws |

**Comments**

- All walls are assumed to have blocking as the structure was constructed pretty recently
- All walls are assumed to be properly connected to the diaphragms
- Ws is the cumulative seismic weight of the structure (546.8 kN), which includes the weight from upper floors, weight of walls, diaphragm, and live load
- Although there is no E-W LDRS in the interior (the existing E-W walls are not part of the LDRS), the exterior E-W LDRS is deemed to be able to handle the demand in the E-W direction

### 2.2.3 Lower Floor LDRS

| Shaking Dir. | Location | Prototype No. | Description | Max. DDL | Capacity |
|---|---|---|---|---|---|
| N-S | Exterior | C-5 | Concrete wall | 1% | 336% Ws |
| | Interior | W-1 | Blocked shearwall | 2.5% | 1.77% Ws |
| E-W | Exterior | C-5 | Concrete wall | 1% | 171% Ws |
| | Interior | W-1 | Blocked shearwall | 2.5% | 2.33% Ws |

**Comments**

- Most of the exterior walls are made out of concrete (25 MPa strength, 2350 kg/m$^3$ density) with approx. 34 mm thickness which has a very high shear capacity compared to wood
- All walls are assumed to have blocking as the structure was constructed pretty recently
- All walls are assumed to be properly connected to the diaphragms and foundation
- Ws is the cumulative seismic weight of the structure (1723.3 kN), which includes the weight from upper floors, weight of walls, diaphragm, live load, and snow

## 2.3 Diaphragms

### 2.3.1 Roof Level Diaphragm

| Shaking Direction | Prototype No. | Description | Span | Max. Movement | Capacity |
|---|---|---|---|---|---|
| N-S | D-3 | Flexible diaphragm – horizontal boards | 12.2 m | 90 mm | 19.86% Wd |
| E-W | D-3 | Flexible diaphragm – horizontal boards | 7.2 m | 90 mm | 17.76% Wd |

**Comments**

- Roof diaphragm is assumed to be built with 64 mm to 89 mm thick T&G decking (with no side spikes) spanning about 2 m between supporting beams
- The maximum movement is governed by 3.0% drift limit of the 3 m wall height
- The diaphragm is assumed to be composed of 2 systems in the N-S direction and 3 systems in the E-W direction
- Wd is the lumped seismic weight at the diaphragm's level (165.3 kN), which includes the weight of roof, snow, and half of the wall's

### 2.3.2 Upper Floor Diaphragm

| Shaking Direction | Prototype No. | Description | Span | Max. Movement | Capacity |
|---|---|---|---|---|---|
| N-S | D-1 | Flexible blocked diaphragm | 11.8 m | 90 mm | 18.28% Wd |
| E-W | D-1 | Flexible blocked diaphragm | 7.2 m | 90 mm | 22.50% Wd |

**Comments**

- Upper floor diaphragm is assumed to be built with 64 mm to 89 mm thick T&G decking (with 6 mm dia. 200 mm long side spikes at 750 mm spacing) spanning about 3 m between supporting beams
- The maximum movement is governed by 3% drift limit of the 3 m wall height
- The diaphragm is assumed to be composed of 1 system in the N-S direction and 2 systems in the E-W direction
- Wd is the lumped seismic weight at the diaphragm's level (334.9 kN), which includes half of the wall's weight above and below the diaphragm, the weight of diaphragm, and live load

### 2.3.3 Main Floor Diaphragm

| Shaking Direction | Prototype No. | Description | Span | Max. Movement | Capacity |
|---|---|---|---|---|---|
| N-S | D-1 | Flexible blocked diaphragm | 11.8 m | 30 mm | 15.83% Wd |
| E-W | D-1 | Flexible blocked diaphragm | 7.2 m | 30 mm | 14.62% Wd |

**Comments**

- Main floor diaphragm is assumed to be built with 64 mm to 89 mm thick T&G decking (with 6 mm dia. 200 mm long side spikes at 750 mm spacing) spanning about 3 m between supporting beams
- The maximum movement is governed by 1% drift limit of the 3 m wall height
- The diaphragm is assumed to be composed of 2 systems in the N-S direction and 3 systems in the E-W direction
- Wd is the lumped seismic weight at the diaphragm's level (773.2 kN), which includes half of the wall's weight above and below the diaphragm, the weight of diaphragm, live load, and snow

## 2.4 Risk Assessment Results

| Element | Shaking Dir. | Loc. | Prototype No. | Capacity | PDE/PSE | RPR |
|---|---|---|---|---|---|---|
| Roof Level Diaphragm | N-S | | D-3 | 19.86% Wd | 1.2% | L |
| | E-W | | D-3 | 17.76% Wd | 1.7% | L |
| Upper Floor LDRS | N-S | Ext. | W-1 | 17.82% Ws | 0.7% | L |
| | | Int. | W-1 | 12.82% Ws | 1.0% | L |
| | E-W | Ext. | W-1 | 6.77% Ws | 2.1% | M |
| Upper Floor Diaphragm | N-S | | D-1 | 18.28% Wd | 0.9% | L |
| | E-W | | D-1 | 22.50% Wd | 0.9% | L |
| Main Floor LDRS | N-S | Ext. | W-1 | 9.01% Ws | 1.5% | L |
| | | Int. | W-1 | 3.11% Ws | 5.6% | H3 |
| | E-W | Ext. | W-1 | 3.64% Ws | 4.5% | M |
| Main Floor Diaphragm | N-S | | D-1 | 15.83% Wd | 1.1% | L |
| | E-W | | D-1 | 14.62% Wd | 1.3% | L |
| Lower Floor LDRS | N-S | | C-5 | 336% Ws | < 0.3% | L |
| | E-W | | C-5 | 171% Ws | < 0.3% | L |
| | | | | **Maximum** | 5.6% | H3 |

**Comments**

- The LDRS on the main floor is governed by the concrete walls. Since the probability of the concrete walls exceeding 1% drift is less than 0.3%, the wood interior walls are unlikely to fail when the concrete walls are still standing.

**Seismic Deficiencies**

- Upper floor E-W exterior LDRS needs to be improved (medium priority)
- Main floor N-S interior LDRS needs to be improved (H3 priority)
- Main floor E-W exterior LDRS needs to be improved (medium priority)

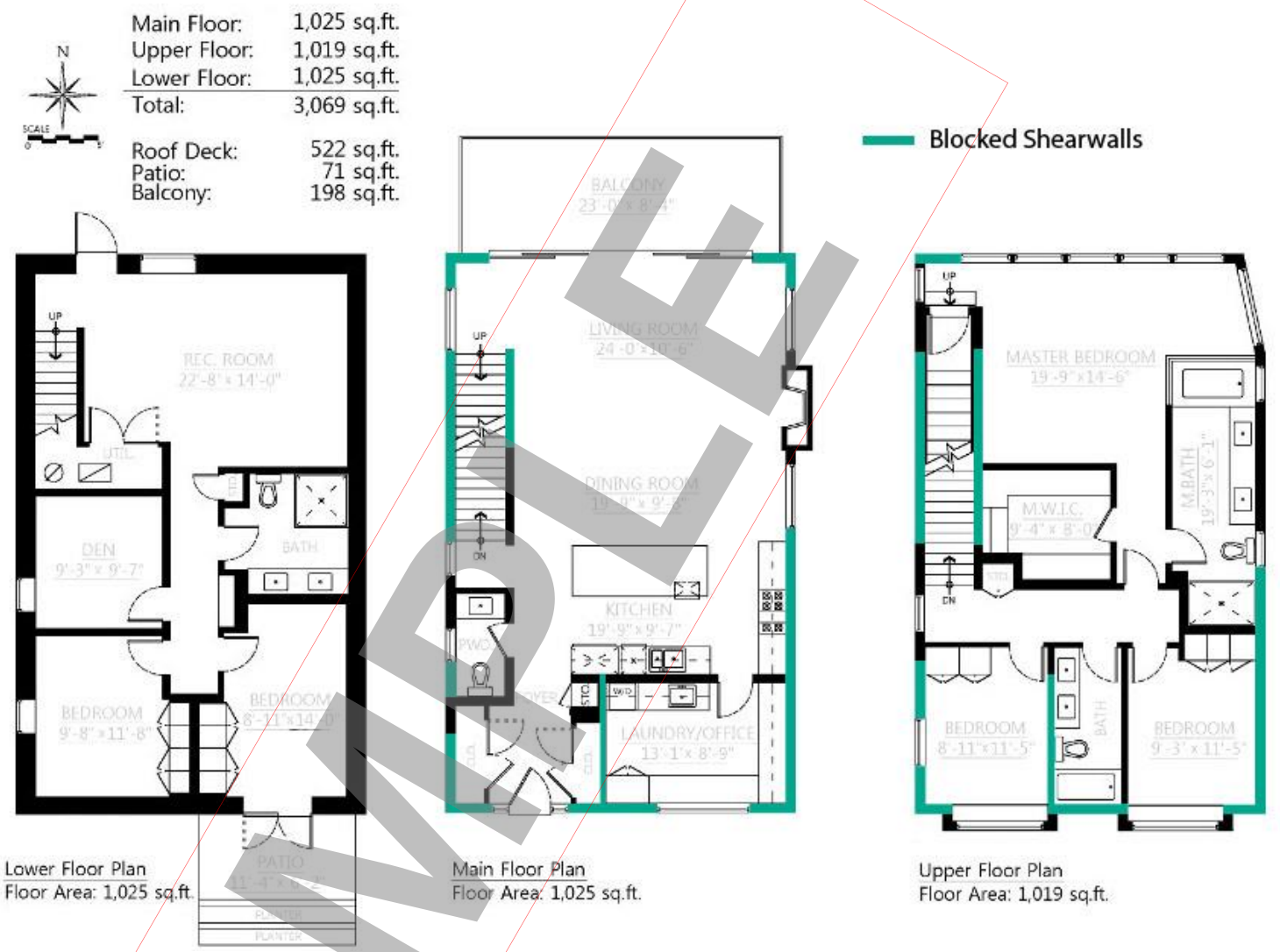


*Figure 2: Locations of the structural walls*

# 3.0 Retrofit Plan

## 3.1 Retrofit Concept

The governing PDE of the house is around 5.6% (H3 retrofit priority), which means that the house is already in a decent shape. However, a life-safety retrofit plan is recommended to lower the PDE to less than 2%. This plan addresses the seismic deficiencies mentioned in the previous section:

- Upper floor E-W exterior LDRS retrofit:
    1. Remove existing wall sheathing of the south (front) wall of the bathroom in the interior and exterior, while maintaining the existing wood frame/electrical/mechanical/insulation when possible
    2. Upgrade the frame by providing adequate nail end distance and better detailing, and replace any damaged wood frame/studs/blockings when necessary
    3. Return the electrical/mechanical/insulation, rebuild the wall sheathing, finish the interior and exterior of the wall
- Main floor N-S interior LDRS retrofit:
    1. Remove existing wall sheathing of the stairs' wall and the wall between the foyer and the office, while maintaining the existing wood frame/electrical/mechanical/insulation when possible
    2. Upgrade the frame by providing adequate nail end distance and better detailing, and replace any damaged wood frame/studs/blockings when necessary
    3. Return the electrical/mechanical/insulation, rebuild the wall sheathing, finish the walls
- Main floor E-W exterior LDRS retrofit:
    1. Remove existing wall sheathing of the exterior E-W walls, while maintaining the existing wood frame/electrical/mechanical/insulation when possible
    2. Upgrade the frame by providing adequate nail end distance and better detailing, and replace any damaged wood frame/studs/blockings when necessary
    3. Return the electrical/mechanical/insulation, rebuild the wall sheathing, finish the interior and exterior of the wall

No changes in the rest of the house.

## 3.2 Risk Assessment Results After Retrofit

| Element | Shaking Dir. | Loc. | Prototype No. | Description | Capacity | PDE/PSE |
|---|---|---|---|---|---|---|
| Upper Floor LDRS | E-W | Ext. | W-1 | Upgraded blocked shearwall | 10.83% Ws | 1.3% |
| Main Floor LDRS | N-S | Int. | W-1 | Upgraded blocked shearwall | 7.92% Ws | 1.7% |
| | E-W | Ext. | W-1 | Upgraded blocked shearwall | 9.26% Ws | 1.5% |

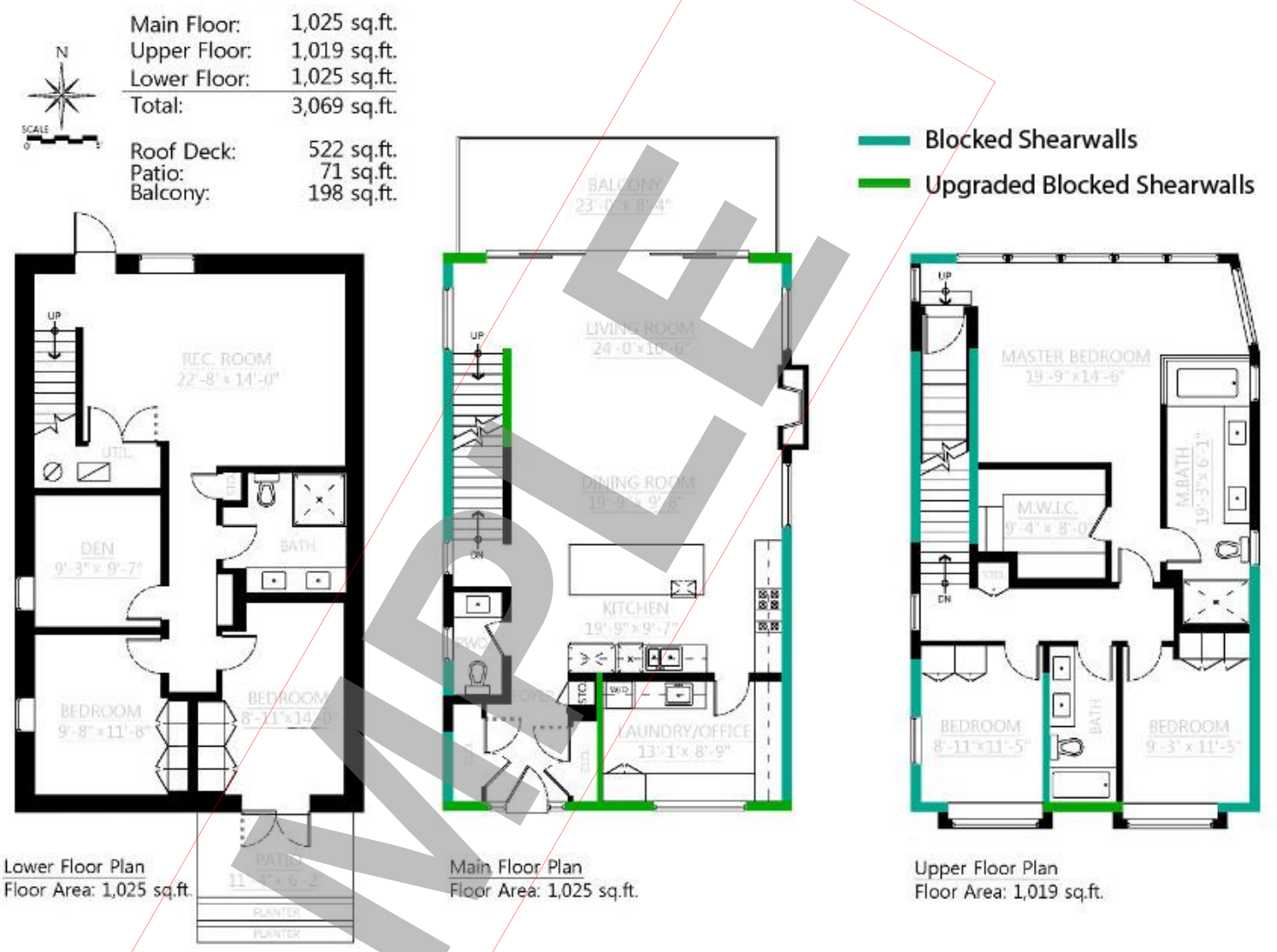


*Figure 3: Locations of the retrofitted structural walls*

# 4.0 Retrofit Cost Estimate

## 4.1 Construction Cost Summary

| Description | Amount ($) |
|---|---|
| **A. Life Safety Retrofit** | |
| 1. Upper floor exterior wall upgrade | 3,649 |
| 2. Main floor interior and exterior wall upgrade | 14,136 |
| 3. Electrical & mechanical work | 2,237 |
| Sub-Total Construction Cost | 20,022 |
| Design Contingency | 3,006 |
| **Total Construction Cost** | **23,028** |
| Gross Floor Area | 285.12 $m^2$ |
| Unit Cost | 81 /$m^2$ |

## 4.2 Construction Cost Breakdown

| Description | Qty. | Unit | Rate ($) | Amount ($) |
|---|---|---|---|---|
| **A. Main Floor Life Safety Retrofit** | | | | |
| 1. Upper floor exterior wall upgrade | | | | |
| Remove existing wall sheathing | 5.1 | $m^2$ | 25 | 128 |
| Wall upgrade: | | | | |
| 38 x 140 @ 400 c/c stud & blocking | 4 | no. | 85 | 340 |
| 12.7 mm plywood to both sides of walls | 5.1 | $m^2$ | 100 | 510 |
| Redo wood dry wall skin | 5.1 | $m^2$ | 60 | 306 |
| Redo exterior wood cladding | 5.1 | $m^2$ | 90 | 459 |
| Paint to interior | 5.1 | $m^2$ | 12 | 61 |
| Paint to exterior | 116.4 | $m^2$ | 13 | 1,513 |
| Allowance for miscellaneous & make good | 10% | % | 3,317 | 332 |
| | | | Sum | 3,649 |
| 2. Main floor interior and exterior wall upgrade | | | | |
| Remove existing wall sheathing | 32.1 | $m^2$ | 25 | 809 |
| Wall upgrade: | | | | |
| 38 x 140 @ 400 c/c stud & blocking | 25 | no. | 85 | 2,125 |
| 12.7 mm plywood to both sides of walls | 32.1 | $m^2$ | 100 | 3,210 |
| Redo wood dry wall skin | 32.1 | $m^2$ | 60 | 1,926 |
| Redo exterior wood cladding | 11.5 | $m^2$ | 90 | 1,035 |
| Paint to interior | 32.1 | $m^2$ | 12 | 385 |
| Paint to exterior | 116.4 | $m^2$ | 13 | 1,513 |
| Allowance for miscellaneous & make good | 10% | % | 10,997 | 1,100 |
| | | | Sum | 12,097 |
| 3. Electrical & mechanical work | | | | |
| Electrical work | 17.2 | $m^2$ | 50 | 860 |
| Mechanical work | 17.2 | $m^2$ | 80 | 1,377 |
| | | | Sum | 2,237 |