CRC Engineering, Inc.

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CE-480 Final Project
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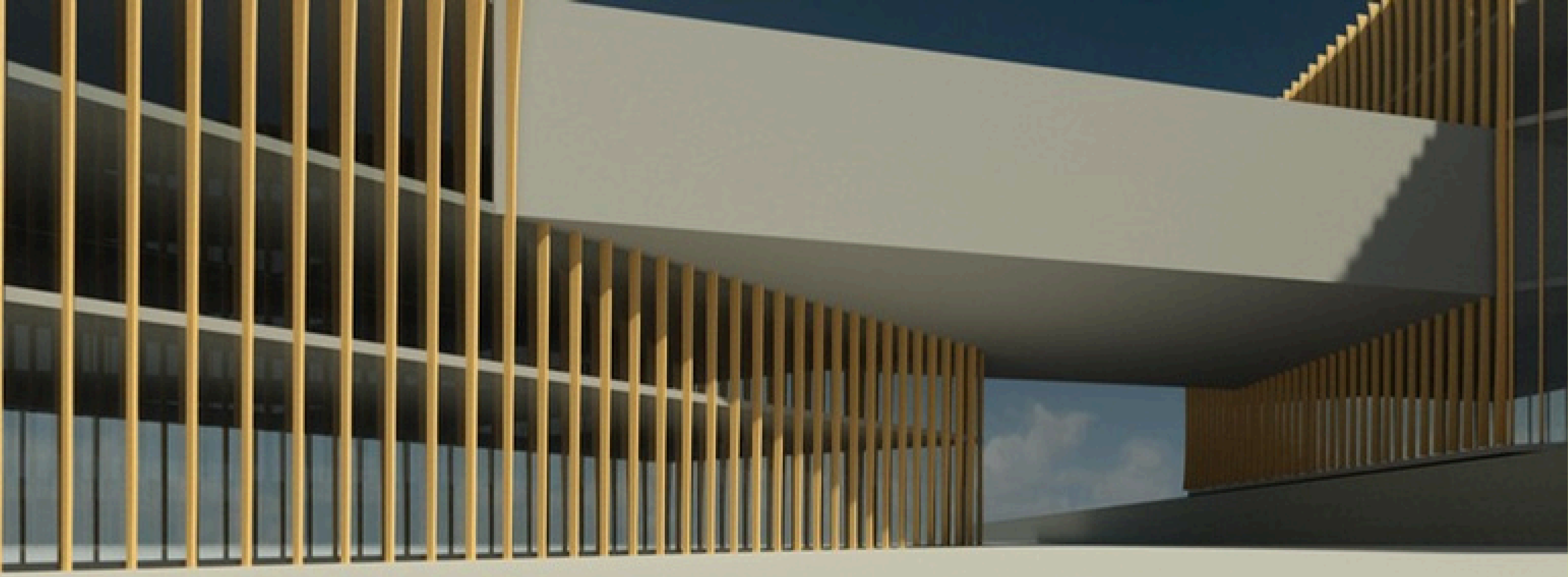


Monday, May 3 2020

CRC Engineering

Santa Monica Living Building

Agenda

Civil

Project Description

Site Overview

Spacial Distribution

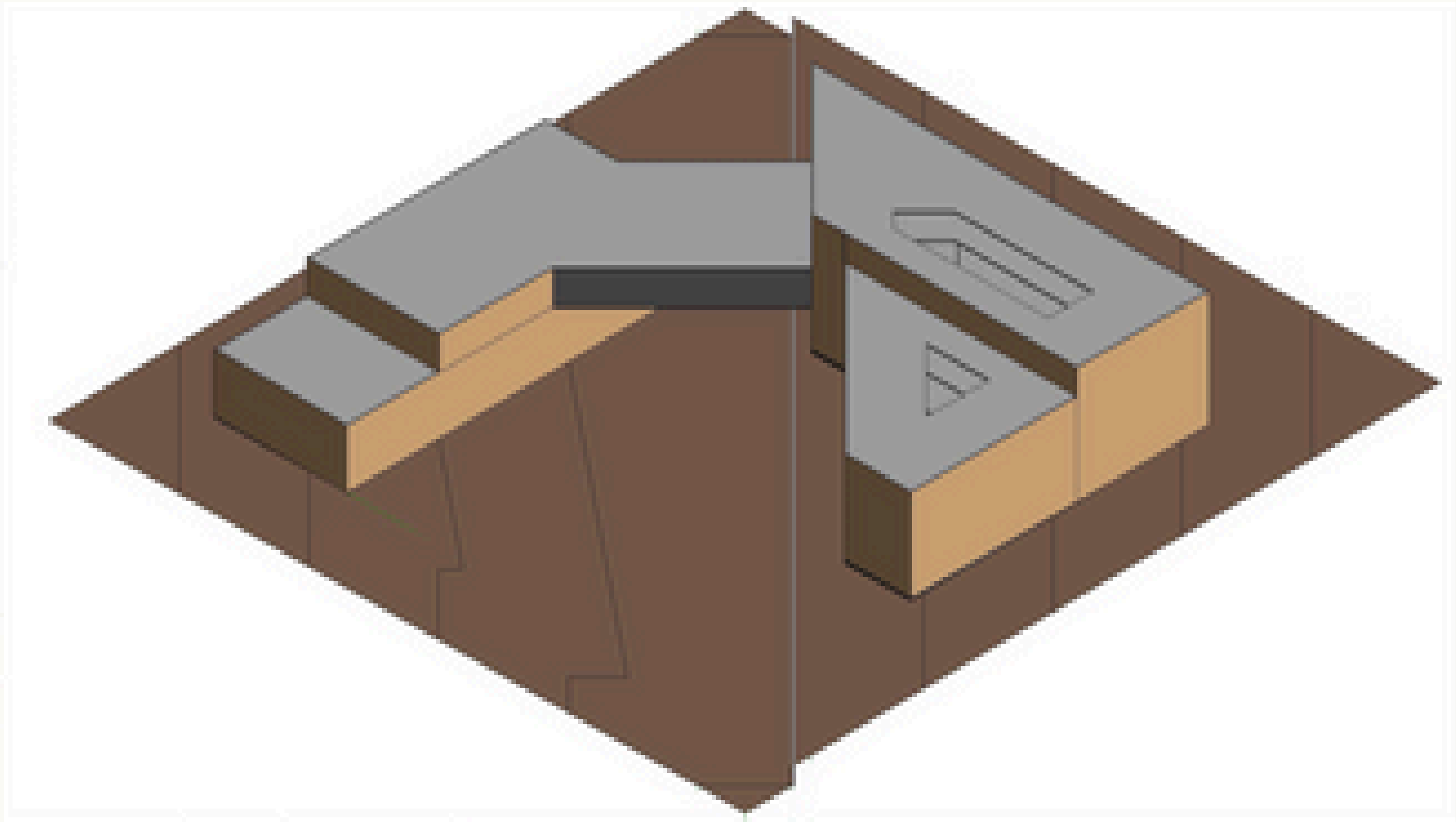
Architectural Features

Building Design

Foundation Design

Cost Analysis

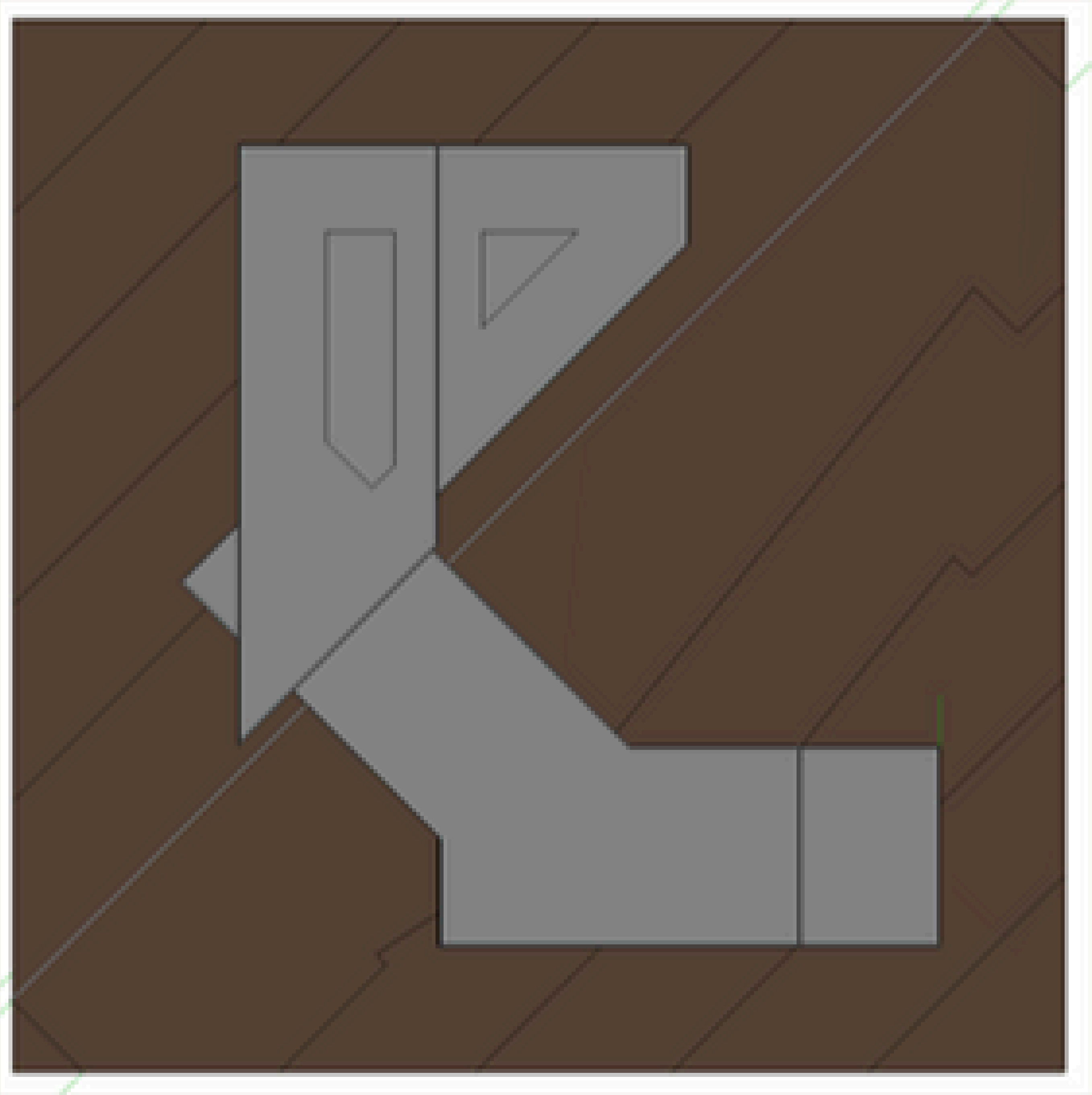
Project Description



- Design a structurally sound building to be used as office space
- Formulate a design considering site conditions, including tracks running through site
- Ensure all structures are resistant to seismic damage

Site Overview

- 50′ setbacks from edge of site observed
- Clearance maintained for train – no structures or footings
- Longest edge of main building facing ocean view
- 3 structurally distinct structures: Main Building, Bridge, Lower Building



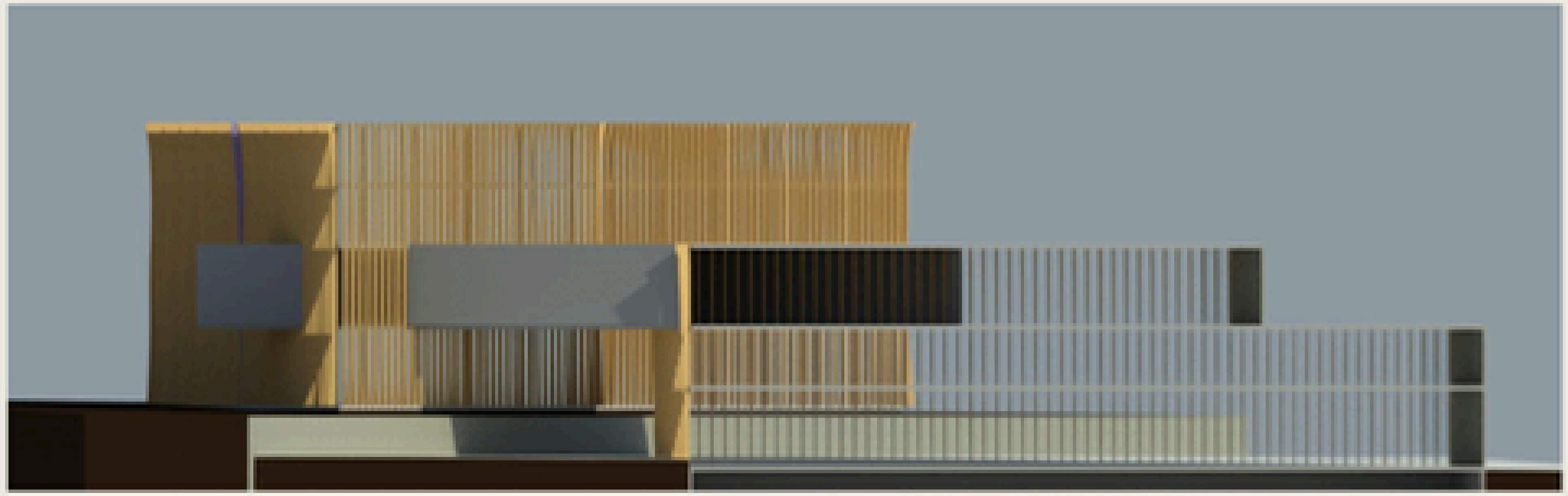
Floor Area Distribution

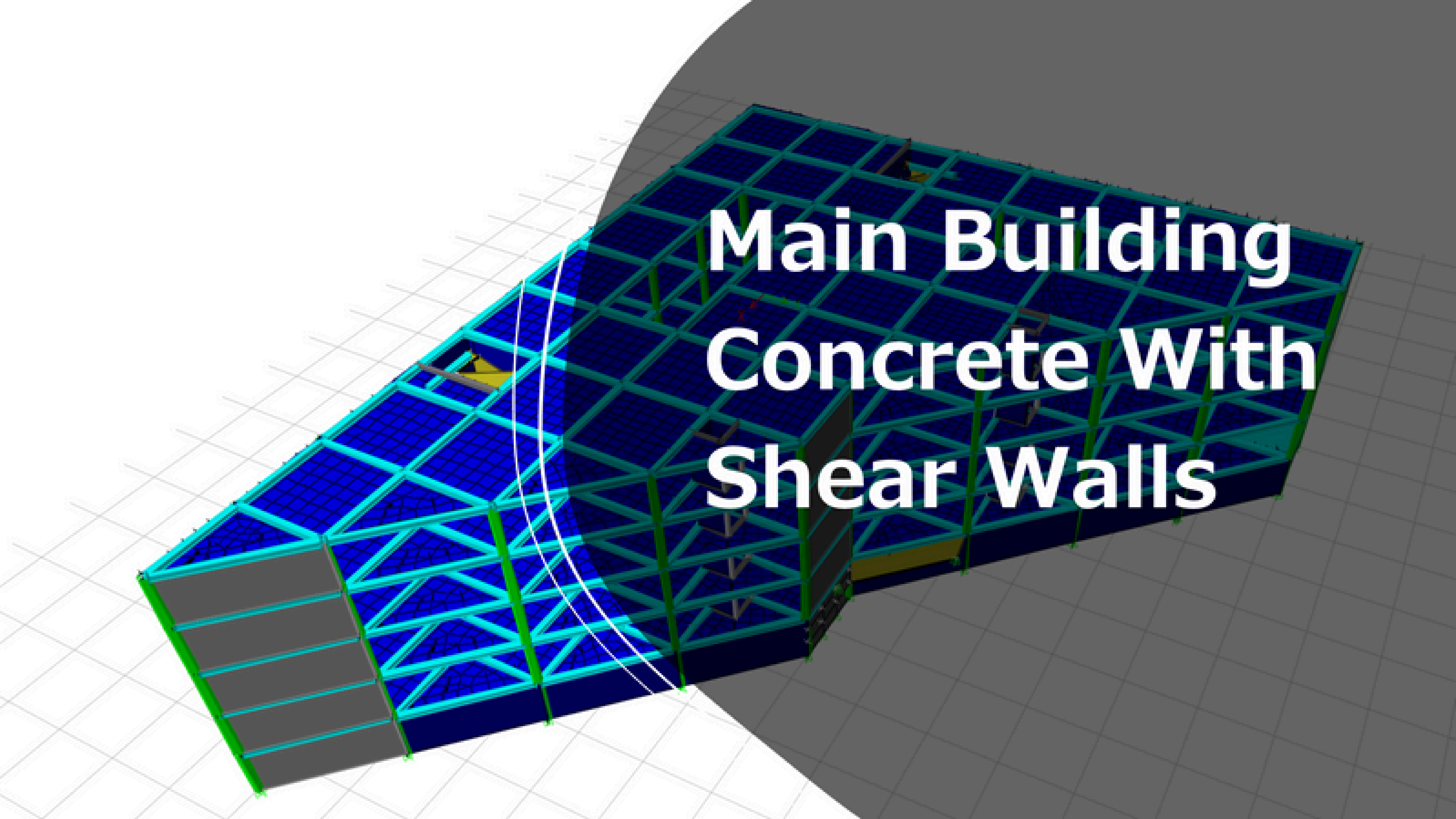
Office Space	109,700 square feet
Office Space Per Capita	180 square feet/person
Coffee/Cafe	1,300 square feet
Grab and Go Food Stand	700 square feet
Recreation Center	16,000 square feet
Shower Rooms (x6)	600 square feet
Control room/Treatment Space	16000 square feet
Total Space	144,300 square feet
Visitors	40
Total maximum occupancy[2]	650 persons

Note: Some basement storage space not included in total

Architectual Design

- Angular structure
- Wooden lavers and concrete bridge – illusion of concrete supported by wood
- Spans train tracks running through site




Main Building
Concrete With
Shear Walls

Key Features of Main Building

4 Story Building with additional Basement for maintenance & Parking Purposes. Each story is 15ft high.

Gross Area for the Building is: 1,37,500 sq/ft. Approx.. 27,500 sqft each floor.

Two open to sky space available for light & air. Approx. 3125 sqft per floor.

Provision for 2 Staircase & 2 Dedicated Area for lift has been given.

Design Parameters

Parameter	Value
Concrete	4000psi, 5000psi
Steel	A615G60
Main Beam	18 in*12in, 5000psi, #9L, #4C
Lift beam	9 in*9in, 5000psi, #9L, #4C
Main Column	20 in*15in, 5000psi, #9L, #4C
Lift Column	12 in*9in, 5000psi, #10L, #4C
Slab	4000psi, 9in
Wall thickness	9in, M2500psi
Shear wall	5000psi, 9in
Ramp	5000psi, 5.5in
Stair	5000psi, 4.5in
Partition wall (WL)	5in, M2500psi
Glass Wall Load (GL)	0.5kip/ft
Partition wall Load (PWL)	0.5kip/ft
Live load (LL)	100 lb/ft2
Mechanical load	20 lb/ft2
RCC Code	ACI 318-14
Steel code	AISC 360-16
Seismic code	ASCE 7-16
Load Combination	1.3(DL+PWL+WL+GL) + 1(LL+EY)

Seismic Parameters

Ss= 1.9794

S1= 0.735

Long Period Transition= 8

Site Class D = D

R = 5

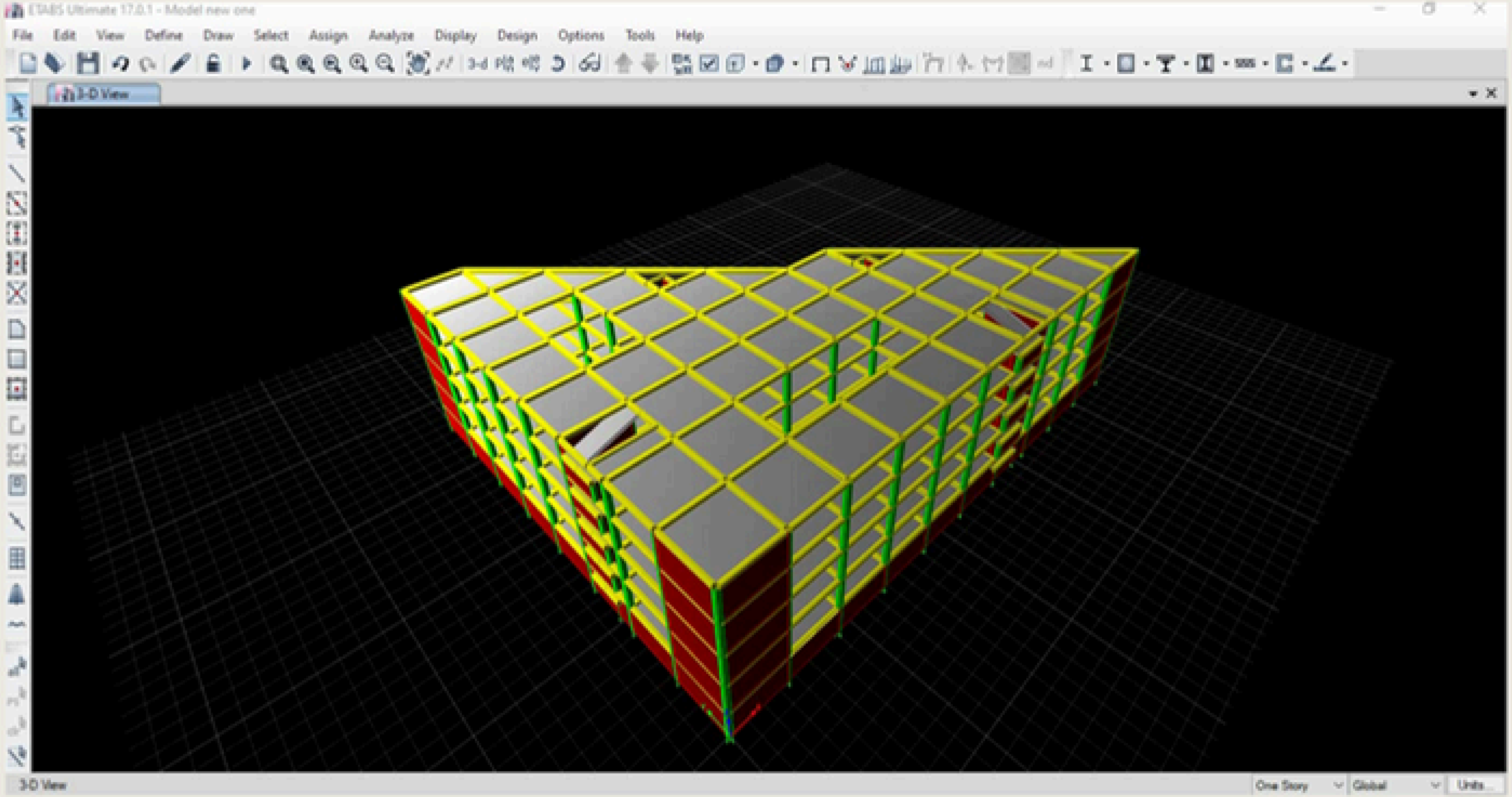
Omega = 2.5

Cd = 5

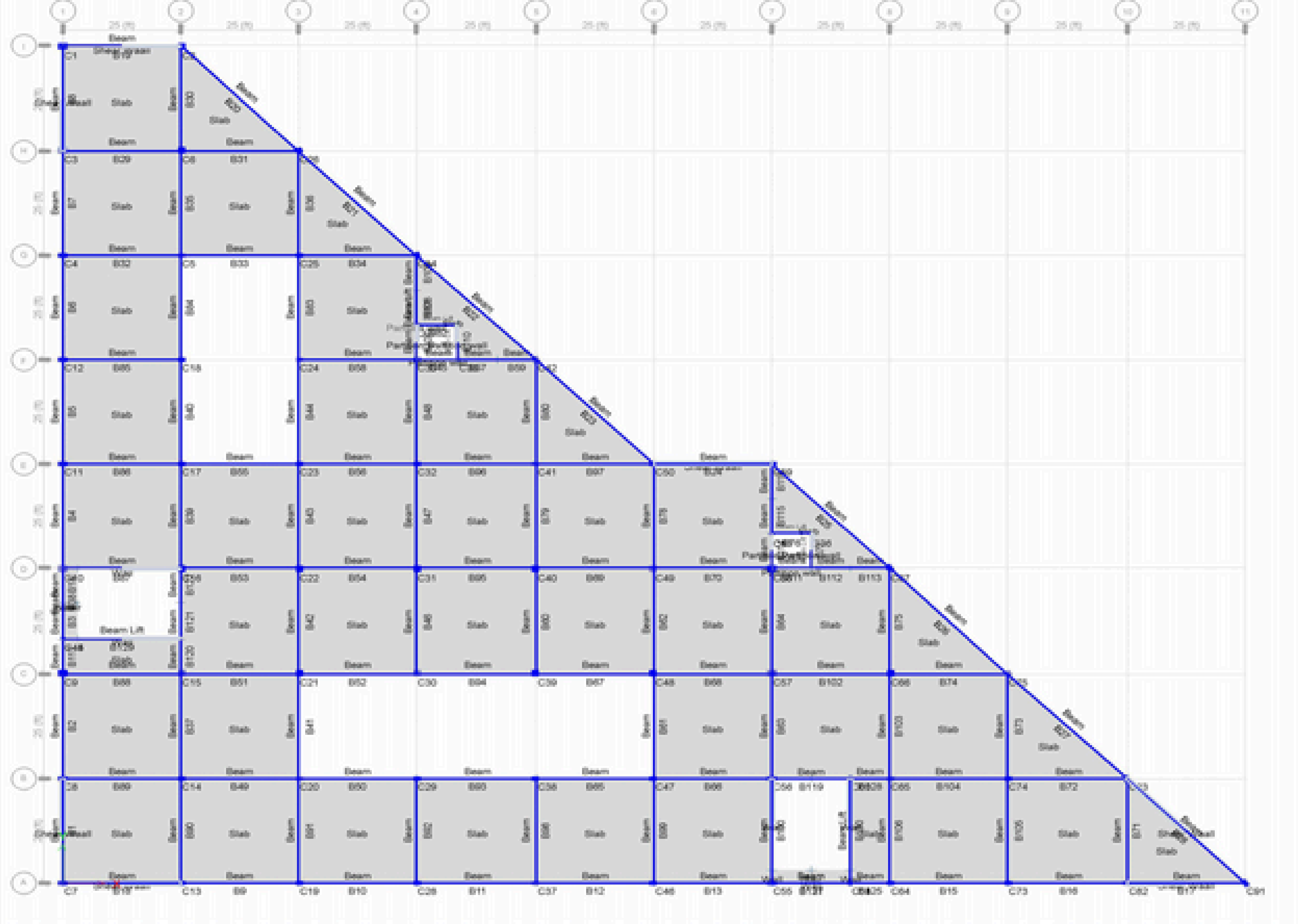
Importance Factor I = 1

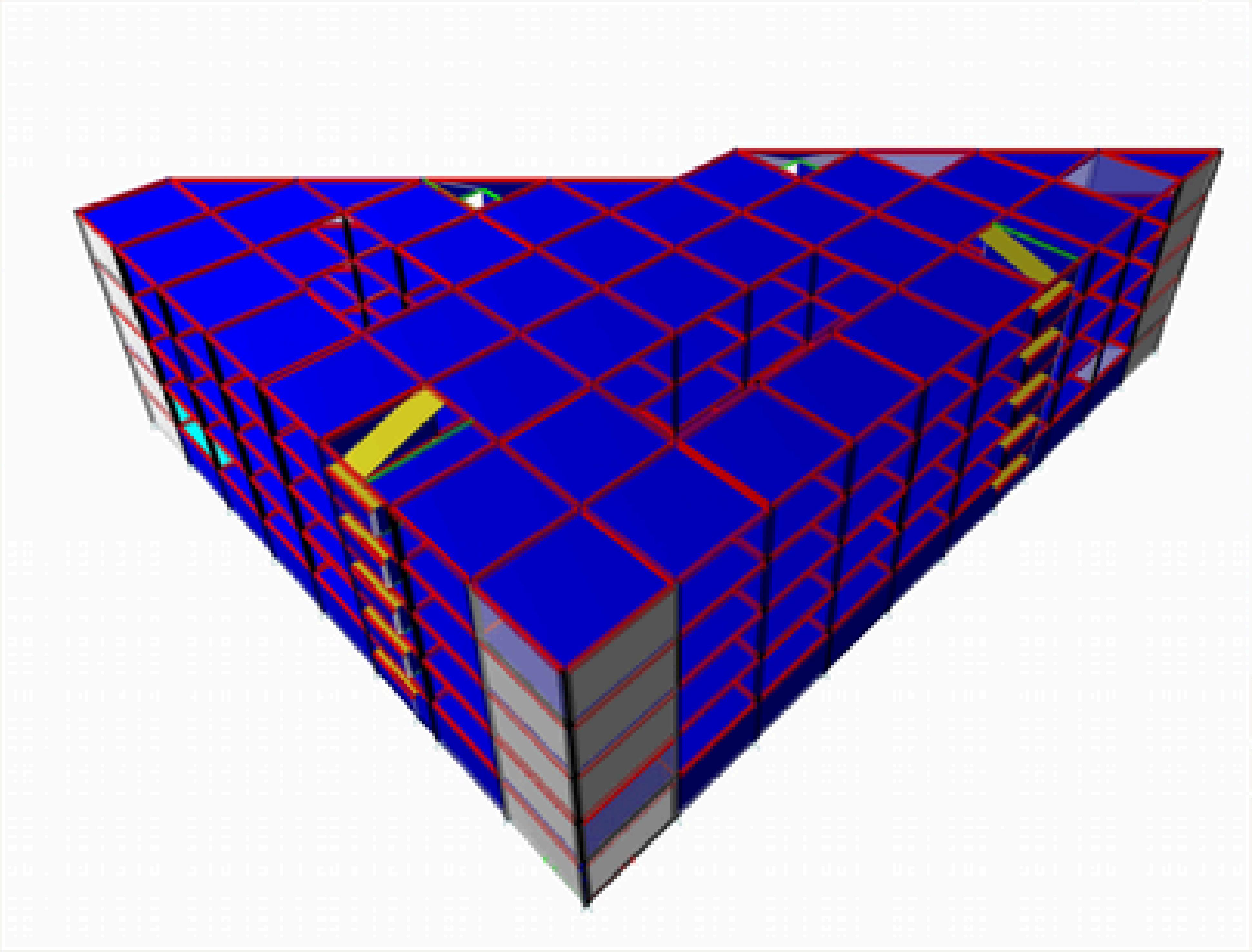
Max Displacement at the Roof = 1.682″

Max Time Period = 0.61 sec < 1 sec



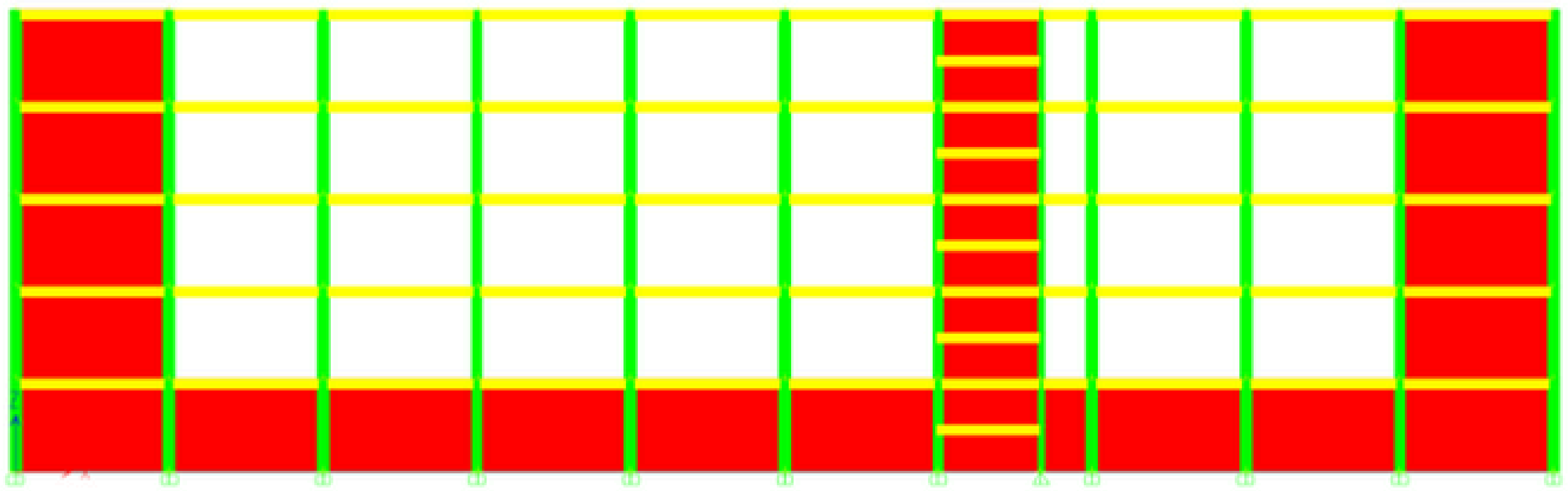
ETABS Ultimate 17.0.1 - Model new one
File Edit View Define Draw Select Assign Analyze Display Design Options Tools Help
3-D View
3-D View
One Story
Global
Units...

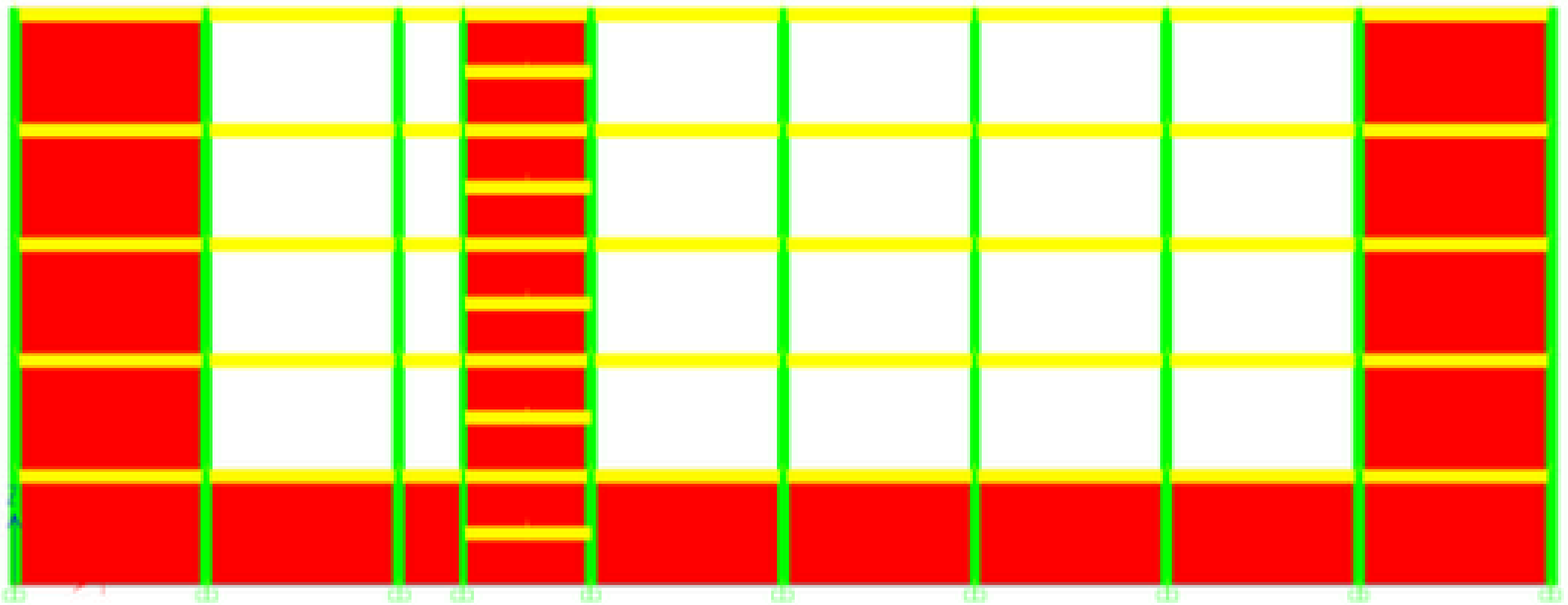




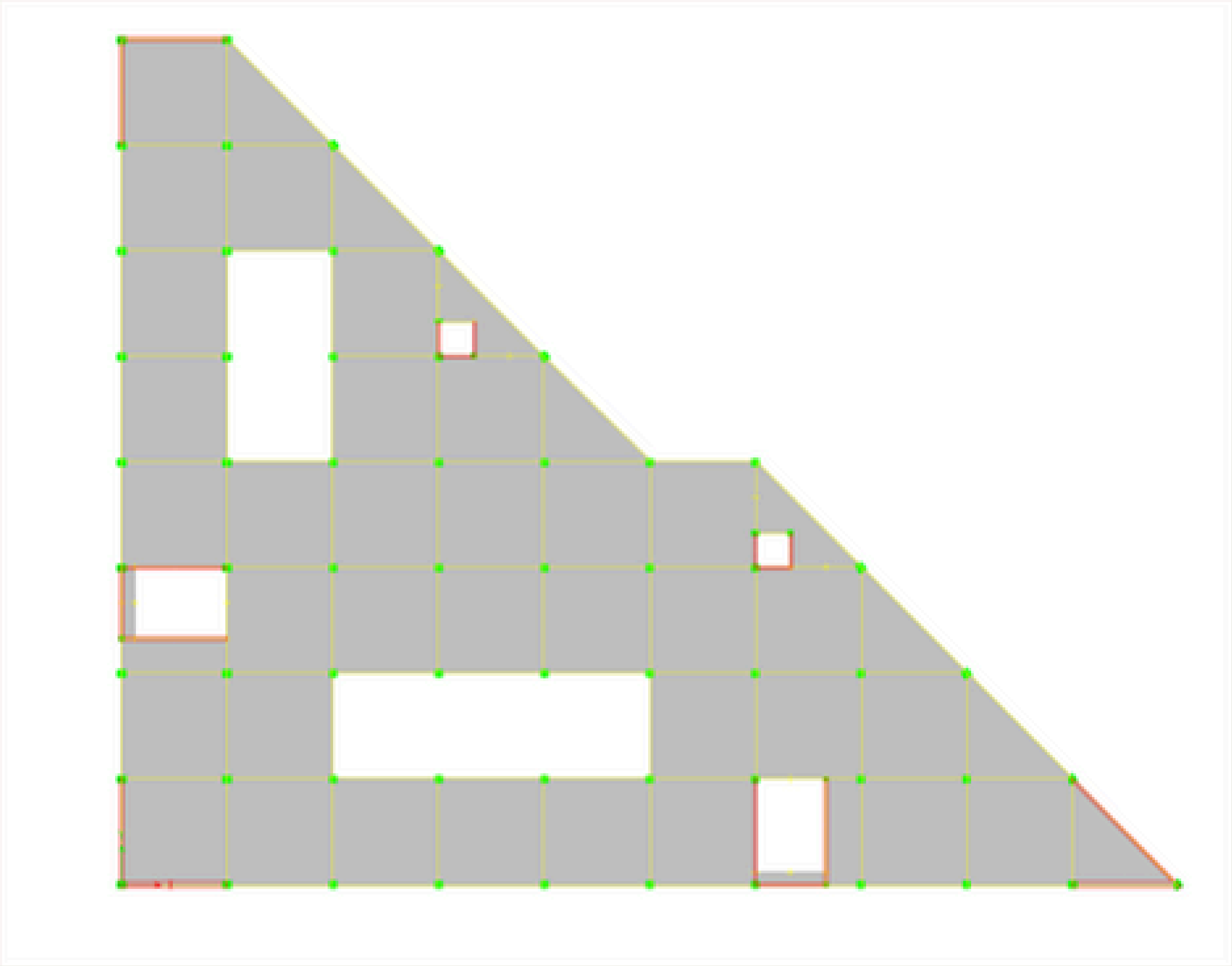
Color Coding

Red: Main Beam
Black: Main Column
Blue: Slab
Grey: Shear Wall
Yellow: Staircase
Green: Lift Beam
Bottom Blue: Wall for Basement
Light Grey: Lift Column





Red Color: Position of Shear Walls



DETAILS OF STRUCTURAL COMPONENTS

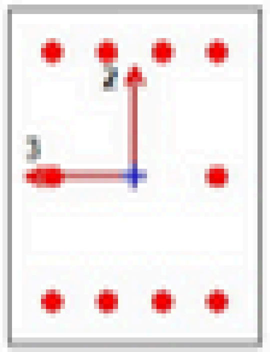
Type	DIMENSIONS	NUMBER PER FLOOR	TOTAL NUMBER
SHEAR WALL	12 in width	7	7
MAIN COLUMN	20 in * 15in * 15ft	59	295
LIFT COLUMN	12 in * 9 in * 15ft	4	20
SLAB	25ft *25ft * 9in	37	185
MAIN BEAM	18in * 12in * 25ft	95 + 8 Inclined	515
LIFT BEAM	9 in * 9 in * 8.333 ft	5	25

We construct **shear walls** to maintain the stability of the structural systems against the lateral loads. The **shear wall** along or together with other structural elements carry the lateral loads applied to buildings**.** Therefore, we **need** to have **shear walls** to resist the lateral loads

Advantages of Shear Wall

- These **walls** provide large strength and stiffness in the direction of orientation.
- Considerably reduces the lateral sway.
- They are easy in construction and implementation.
- It is efficient in terms of construction cost and effectiveness in minimizing earthquake damage.

ACI 318-14 Column Section Design



Column Element Details (Summary)

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (in)	LLRF	Type
Story1	C59	567	Column	UDCon5	162	180	0.562	Sway Special

Section Properties

b (in)	h (in)	dc (in)	Cover (Torsion) (in)
15	20	2.5688	1

Material Properties

E_c (lb/in²)	f'_c (lb/in²)	Lt.Wt Factor (Unitless)	f_y (lb/in²)	f_{ys} (lb/in²)
4030509	5000	1	60000	60000

Design Code Parameters

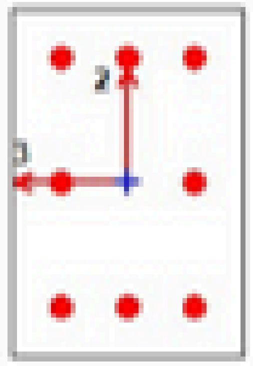
Φ_T	Φ_{CTied}	$\Phi_{CSpiral}$	Φ_{Vns}	Φ_{Vs}	Φ_{Vjoint}	Ω_0
0.9	0.65	0.75	0.75	0.6	0.85	2

Axial Force and Biaxial Moment Design For P_u , M_{u2} , M_{u3}

Design P_u kip	Design M_{u2} kip-ft	Design M_{u3} kip-ft	Minimum M2 kip-ft	Minimum M3 kip-ft	Rebar Area in²	Rebar % %
431.959	-102.4231	-43.1959	37.7964	43.1959	3	1

Axial Force and Biaxial Moment Factors

	C_m Factor Unitless	δ_{ns} Factor Unitless	δ_s Factor Unitless	K Factor Unitless	Effective Length in
Major Bend(M3)	0.320421	1	1	1	162
Minor Bend(M2)	0.241307	1	1	1	162



Column Element Details (Summary)

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (in)	LLRF	Type
Basement	B24	1203	Beam	UDCon5	290	300	1	Sway Special

Section Properties

b (in)	h (in)	dc (in)	Cover (Torsion) (in)
12	18	2.5688	1

Material Properties

E_c (lb/in²)	f'_c (lb/in²)	Lt.Wt Factor (Unitless)	f_y (lb/in²)	f_{ys} (lb/in²)
4030509	5000	1	60000	60000

Design Code Parameters

Φ_T	Φ_{CTied}	$\Phi_{CSpiral}$	Φ_{Vns}	Φ_{Vs}	Φ_{Vjoint}	Ω_0
0.9	0.65	0.75	0.75	0.6	0.85	2

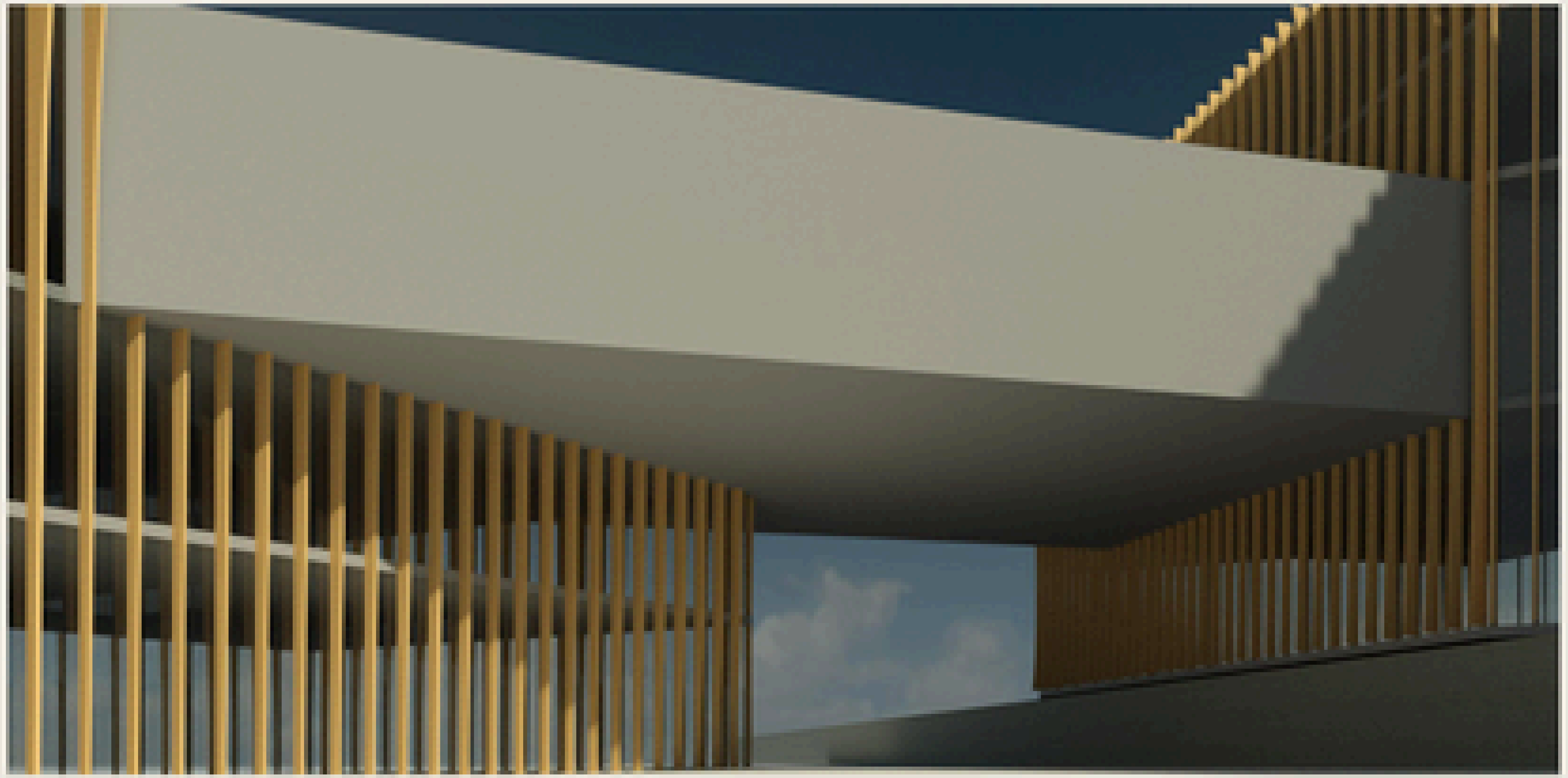
Axial Force and Biaxial Moment Design For P_u , M_{u2} , M_{u3}

Design P_u kip	Design M_{u2} kip-ft	Design M_{u3} kip-ft	Minimum M2 kip-ft	Minimum M3 kip-ft	Rebar Area in²	Rebar % %
-47.249	-1.579	4.944	3.7799	4.4886	2.16	1

Axial Force and Biaxial Moment Factors

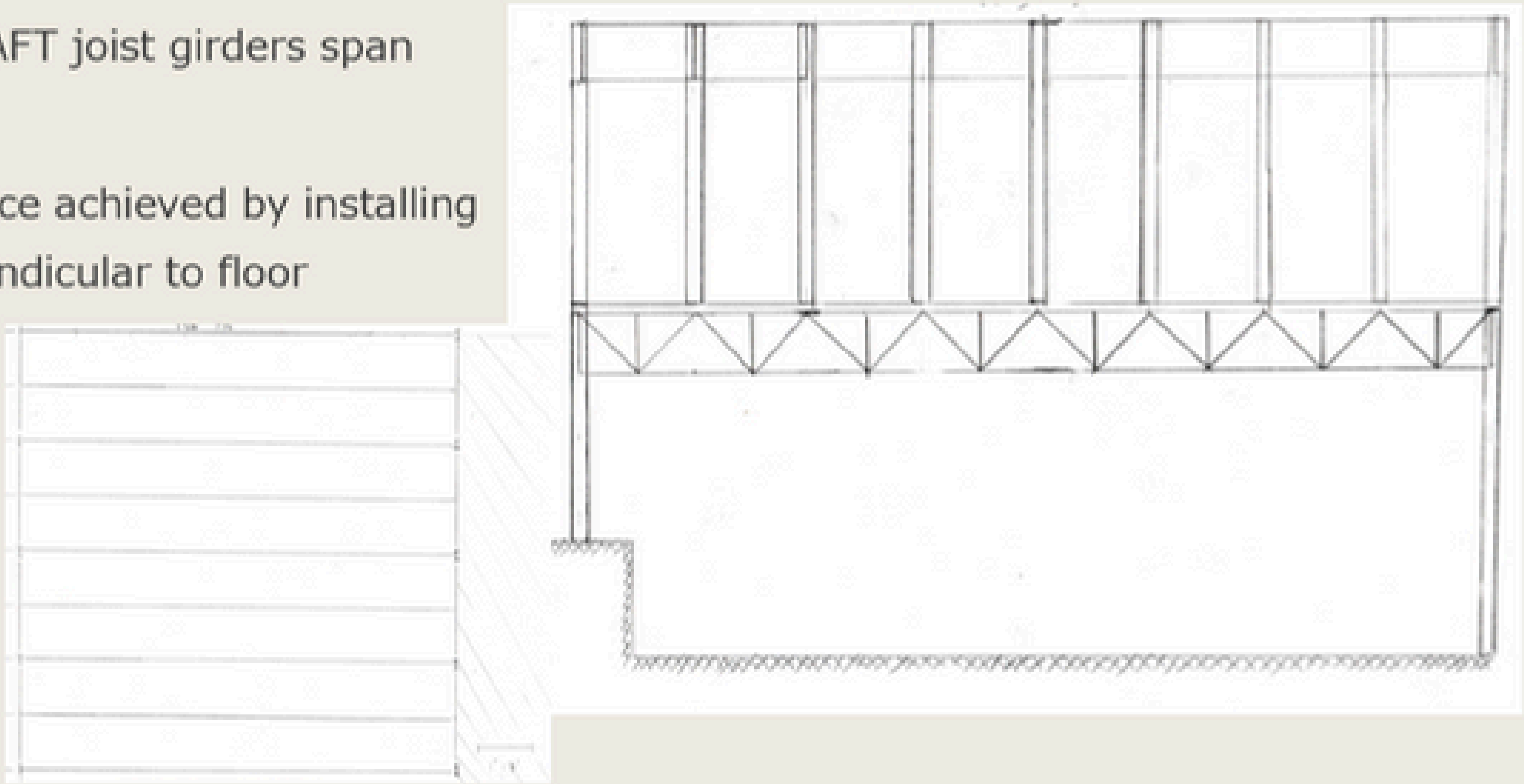
	C_m Factor Unitless	δ_{ns} Factor Unitless	δ_s Factor Unitless	K Factor Unitless	Effective Length in
Major Bend(M3)	1	1	1	1	280
Minor Bend(M2)	1	1	1	1	280

Bridge Design



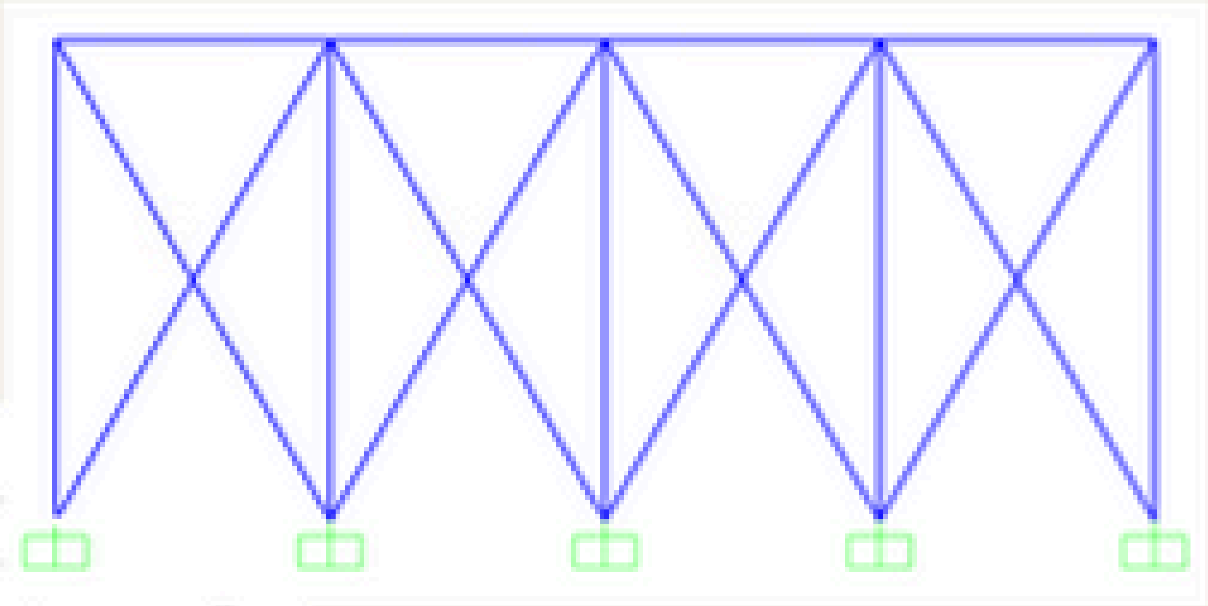
Bridge Structural Design

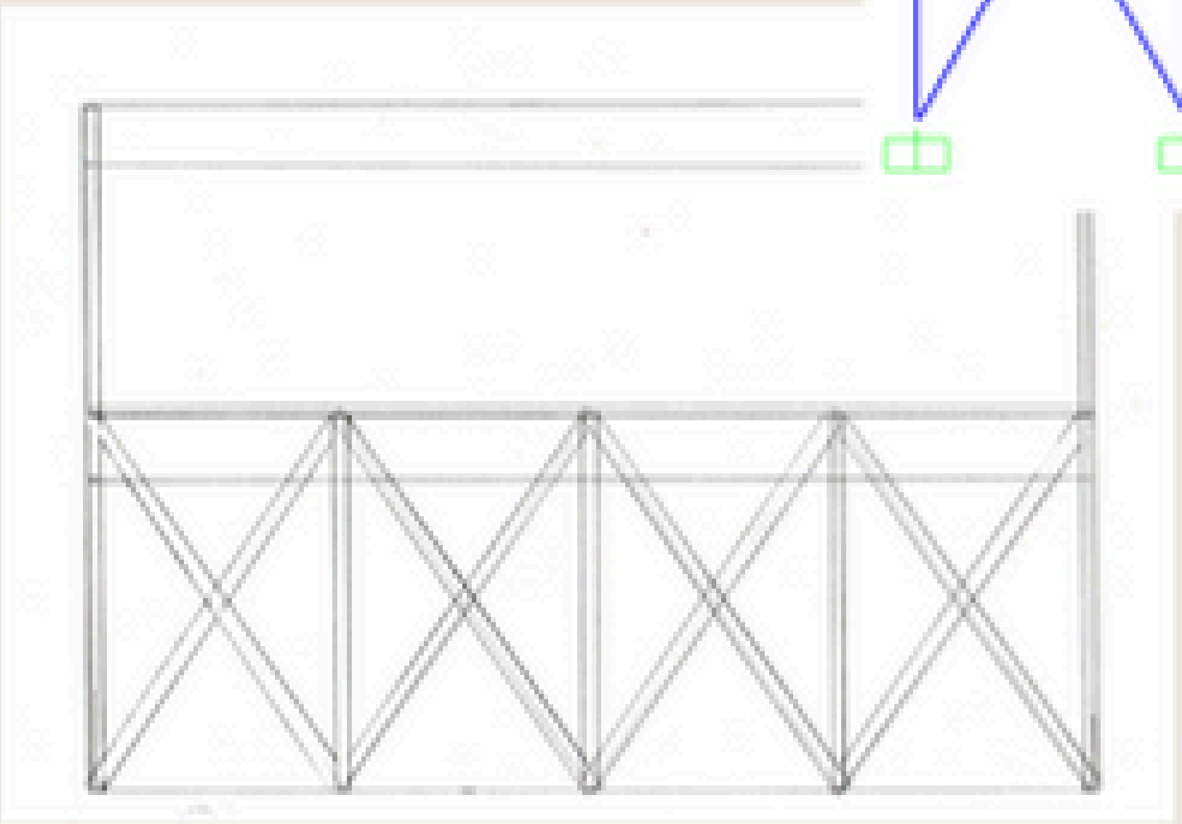
- Webbed VULCRAFT joist girders span 80ft distance
- Column-less space achieved by installing roof joists perpendicular to floor



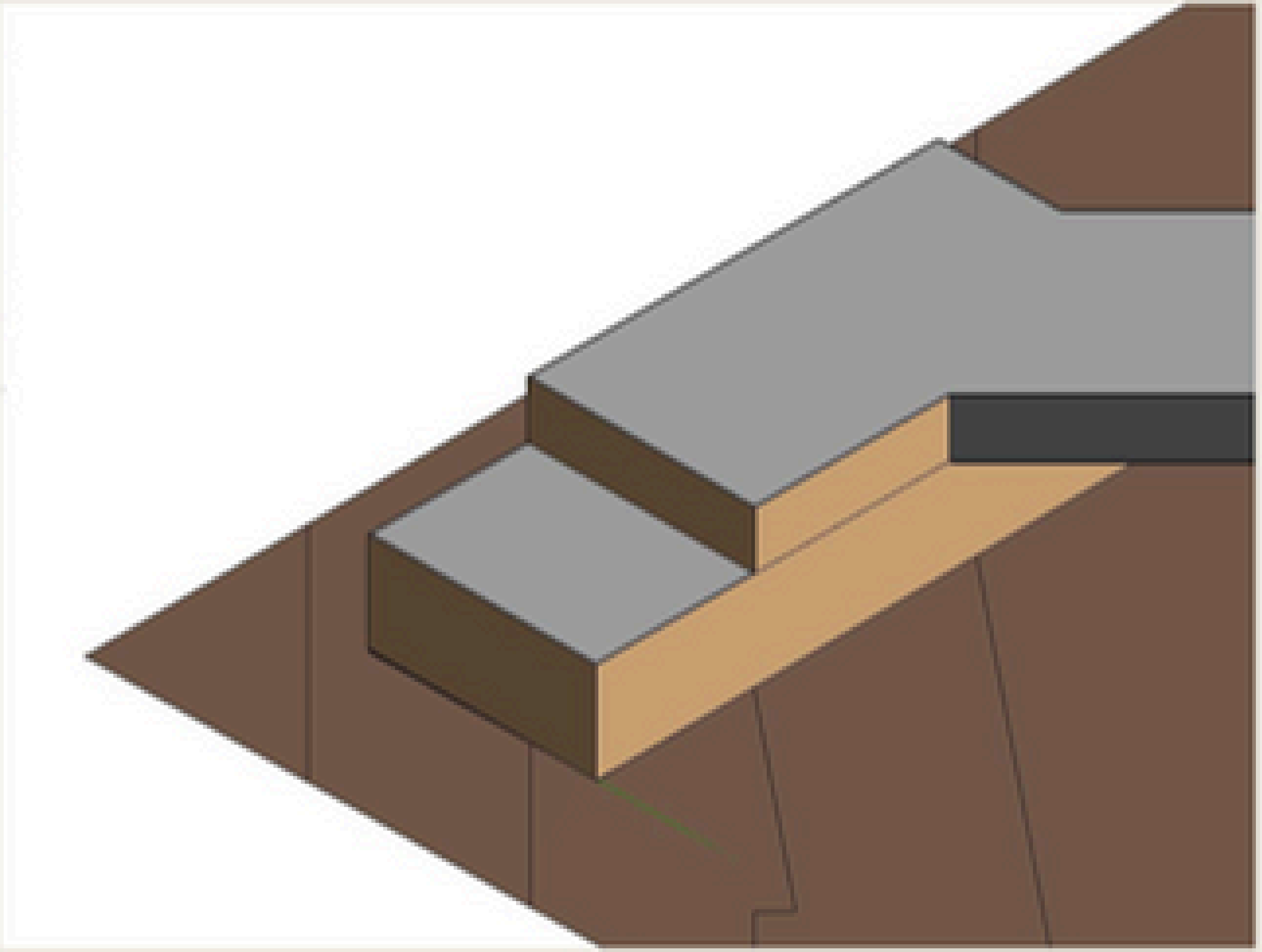
Bridge Seismic Design

- Brace framing used to resist seismic forces
- Bridge supports feature 4 cross braces





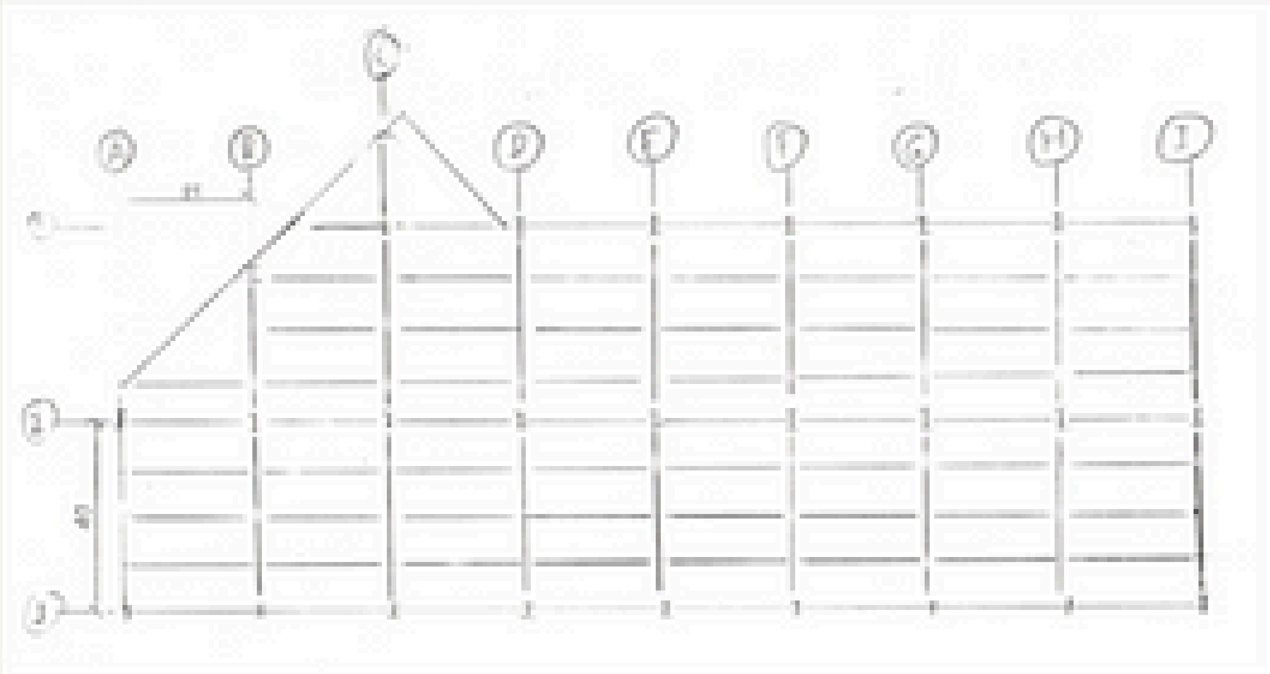
Lower Building Design



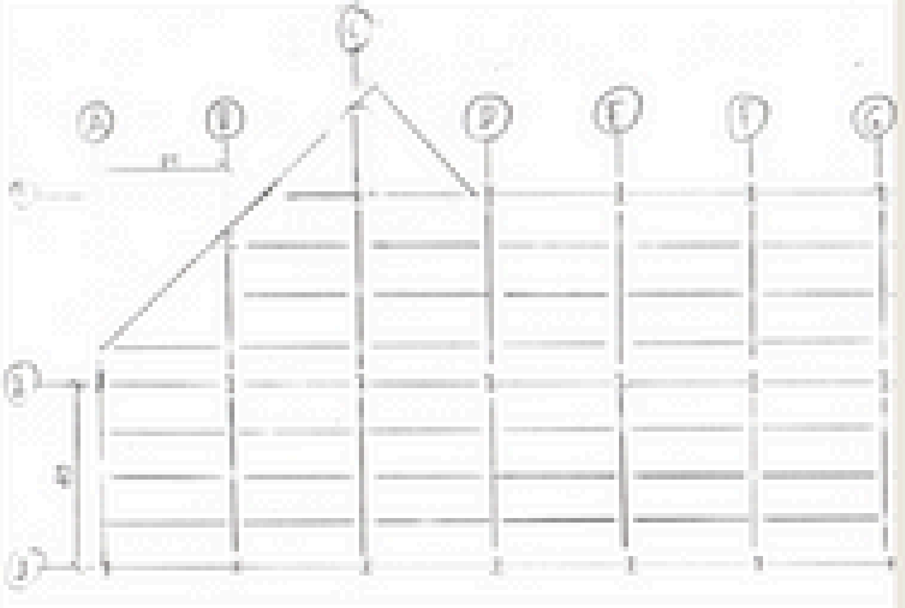
Lower Building Structural Design

- Steel and concrete composite design
- Greatly reduces the amount of steel needed for structure
- Unusual shape allows for seamless compatibility with bridge structure

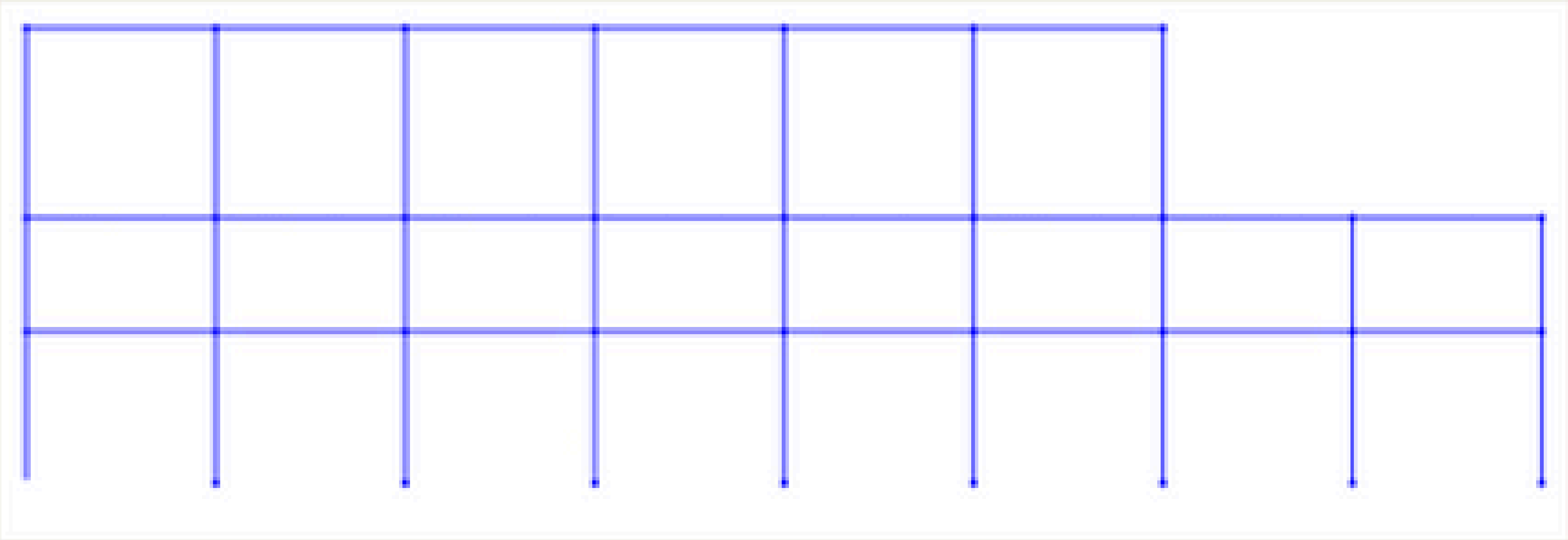
Level 1, 2 & 3



Roof



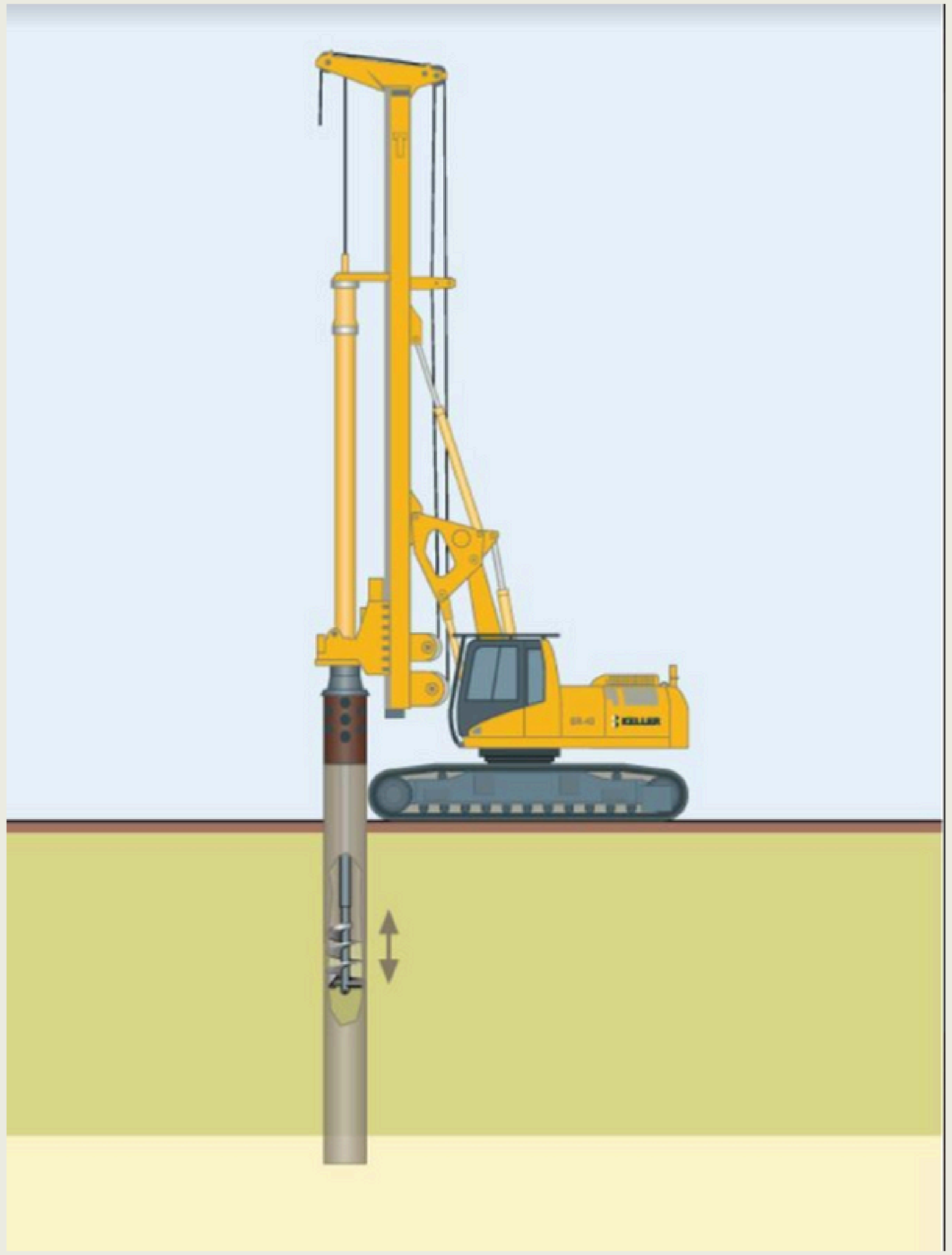
Lower Building Seismic Design



- Special Moment Frame on exterior of building
- Satisfies earthquake code for Santa Monica site
- Structurally independent from other sections of building

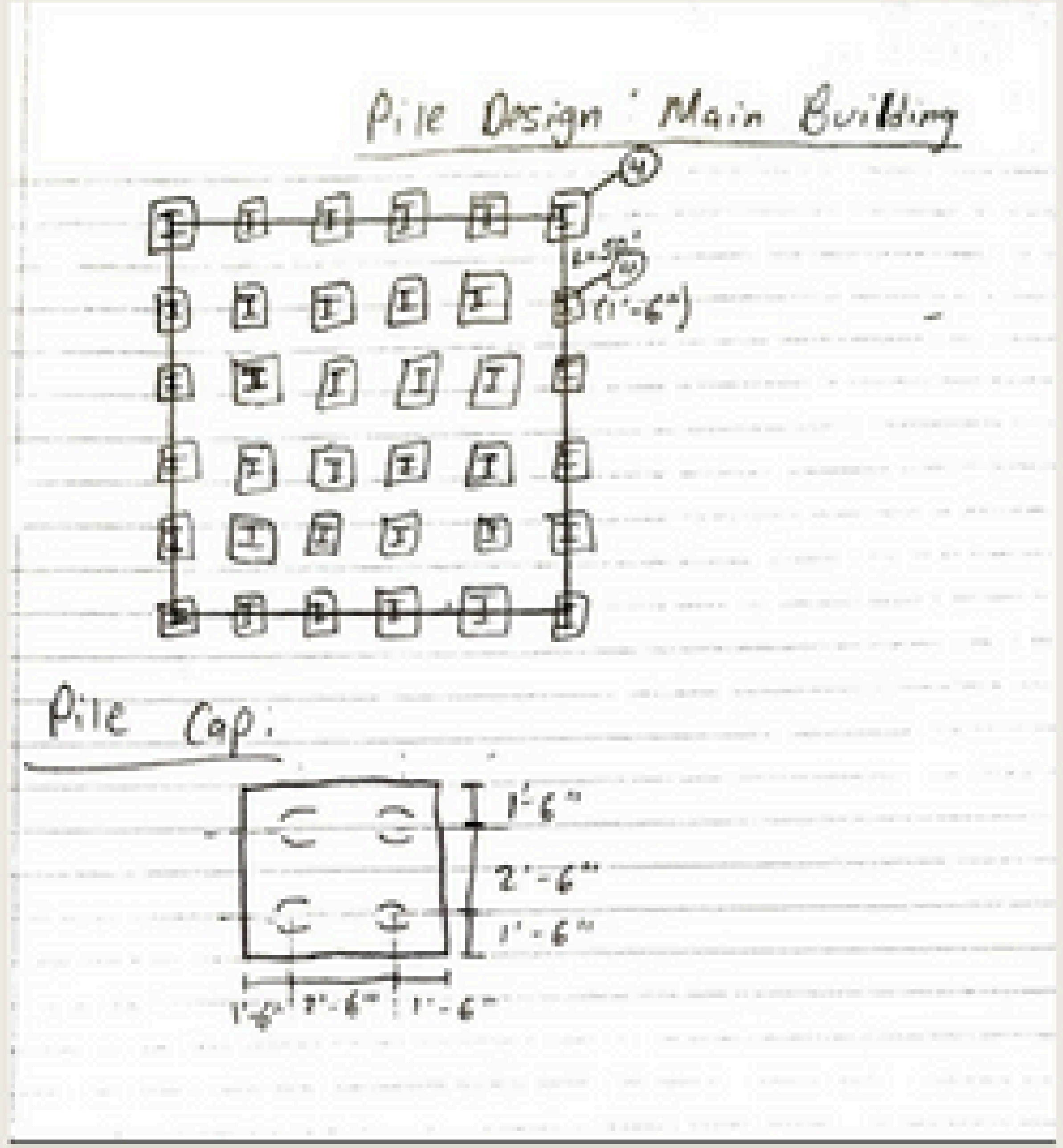
Foundation Design:

Drilled, Cast-in-Place Piles



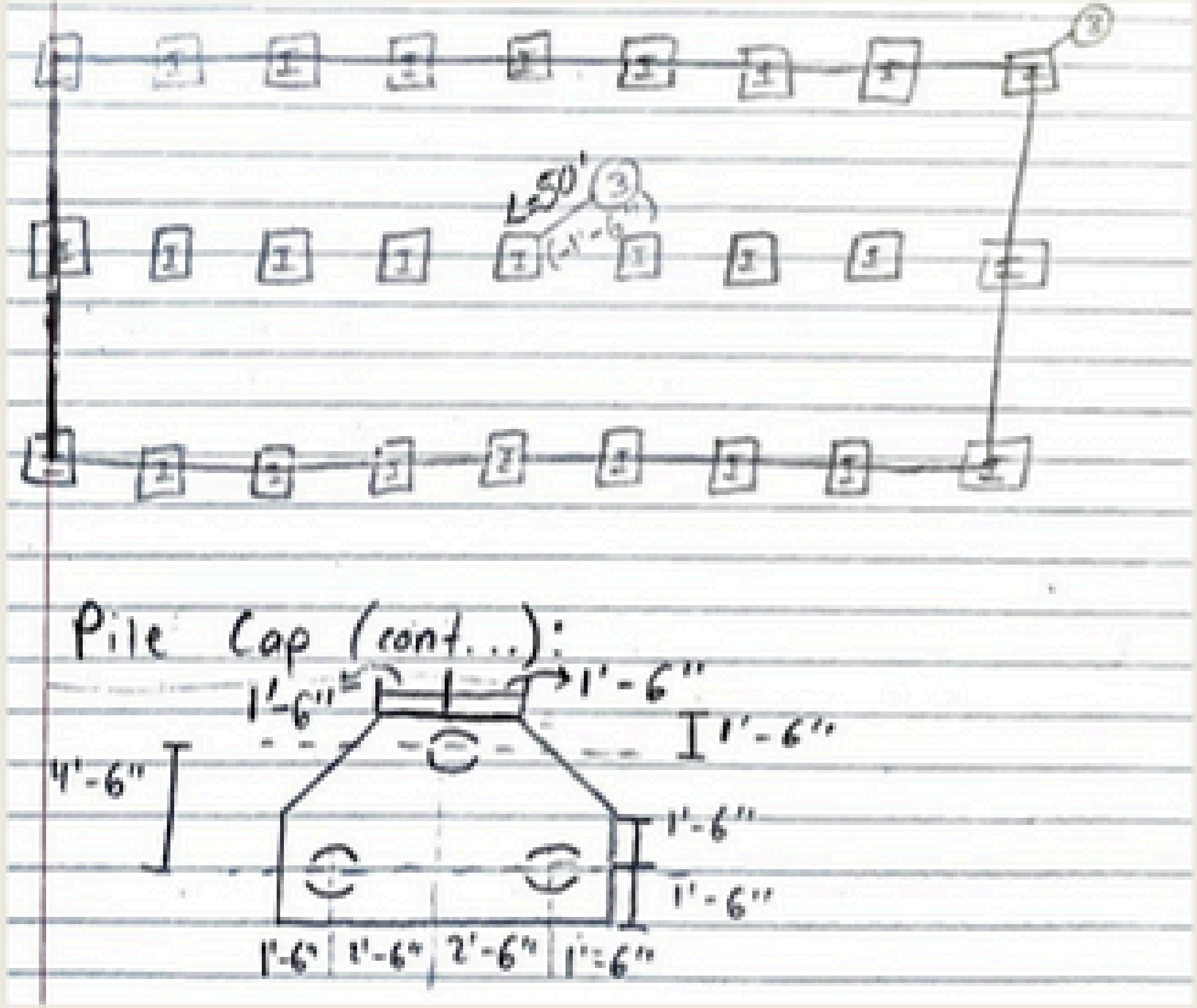
Foundation Design (Main Building)

- Depth of Embedment: 50′-0″
- 24″-diameter piles
- No. of piles: 4
- Pile Cap: Type 4
- Weight of Cap: 33.6 kips
- Dimension of Cap: 8′ x 8′



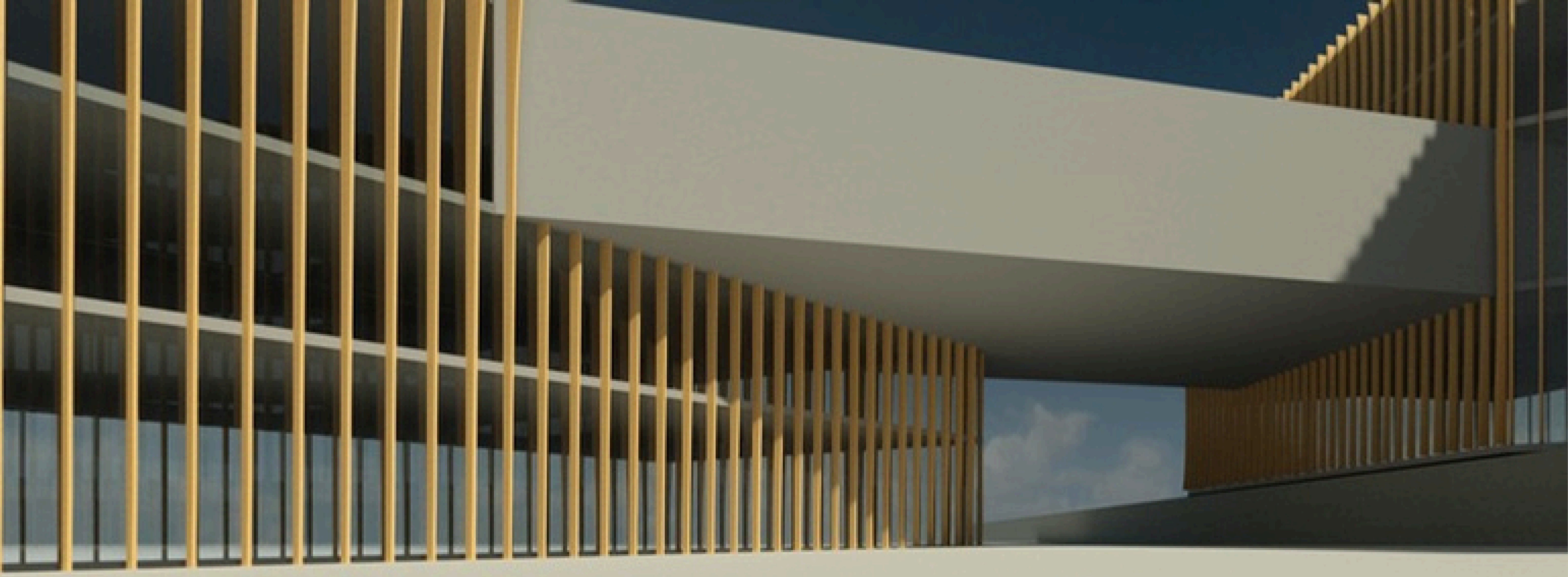
Foundation Design (Lower Building)

- Depth of Embedment: 50′-0″
- 24″-diameter piles
- No. of piles: 3
- Pile Cap: Type 3
- Weight of Cap: 25.6 kips
- Area of Cap: 48 ¾ sqft



Cost Analysis

Total Capital Cost	$58.2 M
MATERIALS	$4,081,250
EQUIPMENT	$5,118,750
LABOR	$37 M
15% CONTINGENCY	$7,050,000
ENVIRONMENTAL	$4,165,775



Monday, May 3 2020

MJSM Consulting

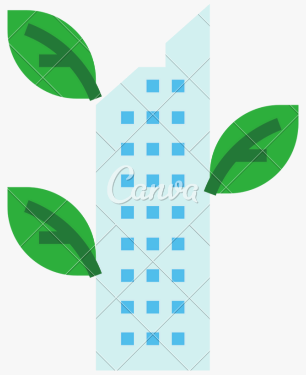
Santa Monica Living Building

MJSM Consulting

Agenda
Environmental

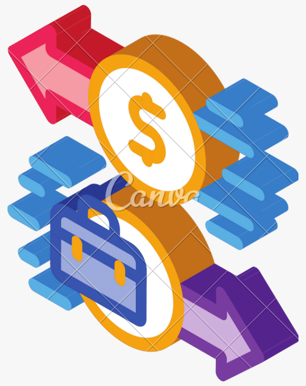
- Project Goal & Living Building Challenge Overview
- Overview of Design
- Water Strategy
- Energy Strategy
- Project Cost & Recommendation
- Performance Guarantee
- Comments on Collaboration
- Q&A

Project Goals



1 Identify environmental requirements and infrastructure needed to support a Living Building

2 Develop engineering solutions and design for the supporting environmental infrastructure, including risk-mitigating solutions



3 Present a business case on the proposed environmental infrastructure and determine its feasibility

Living Building Guidelines

50%

Responsible Water Use

Must use 50% less water than baseline building

100%

Net Positive Water Use

Must supply 100% of water through recycling & closed loop system

70%

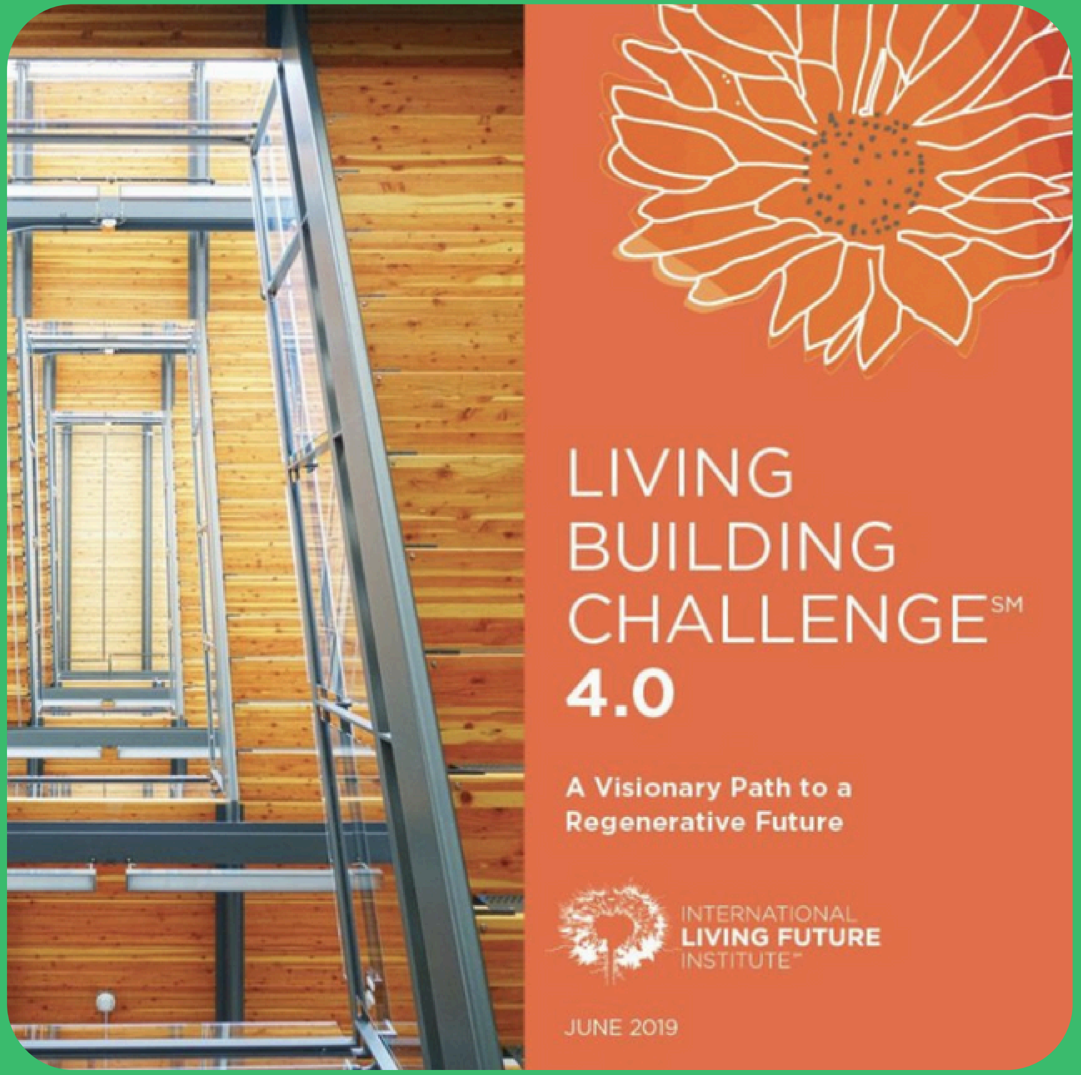
Energy and Carbon Reduction

Must use 70% less energy than baseline building

105%

Net Positive Carbon

Must supply 105% of energy needs through on-site renewable energy



144,300 sqft

650 occupancy

energy-efficient

indirect groundwater recharge

1 million kWh solar annually

on-site composting

6 showers 90/day

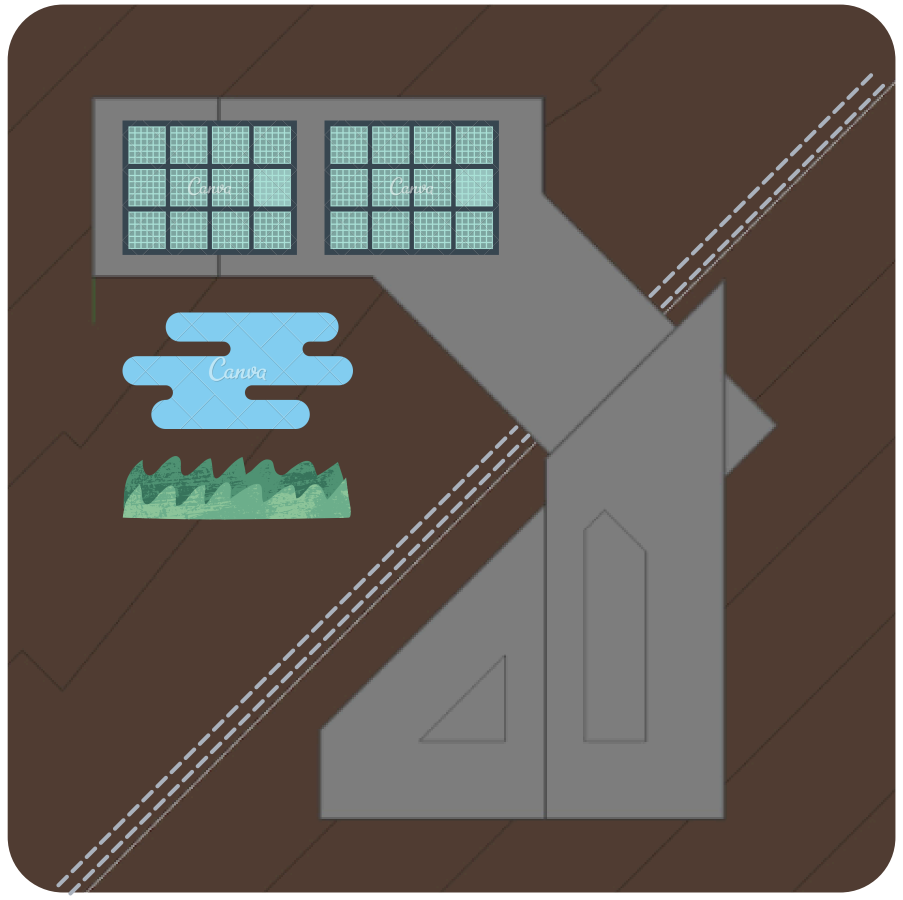
on-site grey water recycling

1-week backup storage

locally-sourced wooden facade

edible agriculture

low-flush toilets



aerial view

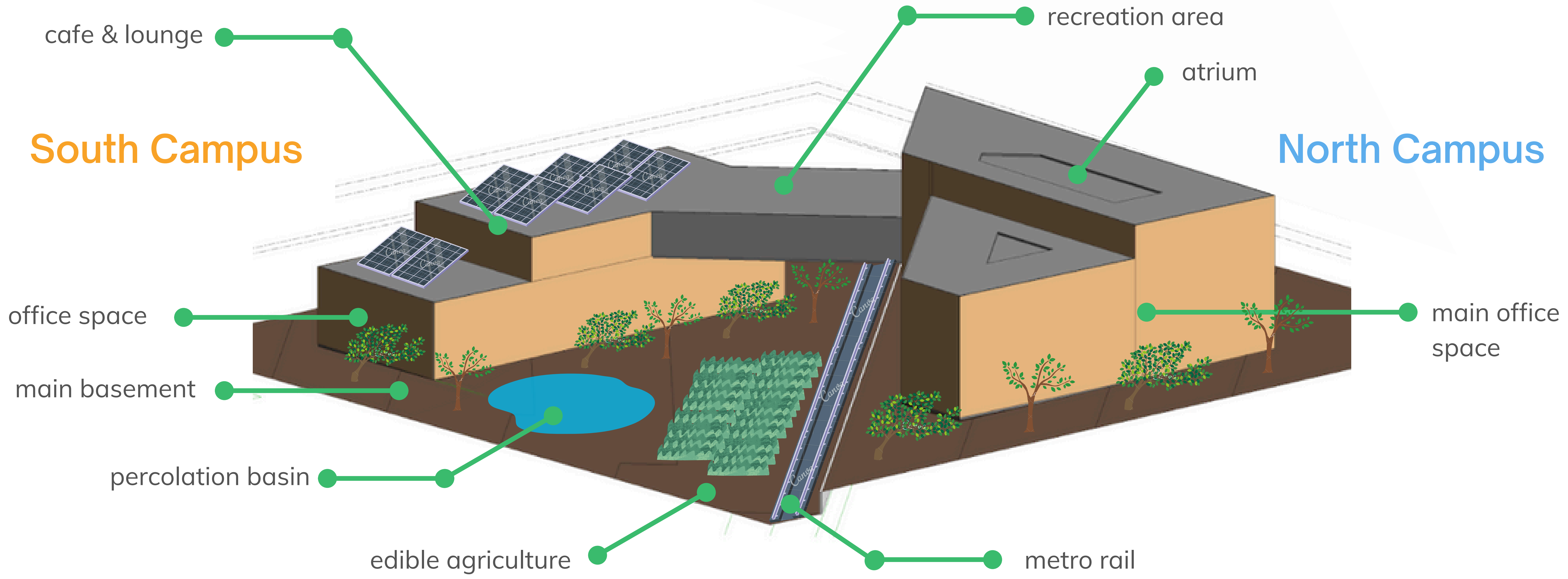
~4,000

gpd water demand

~2500

kWh demand per day

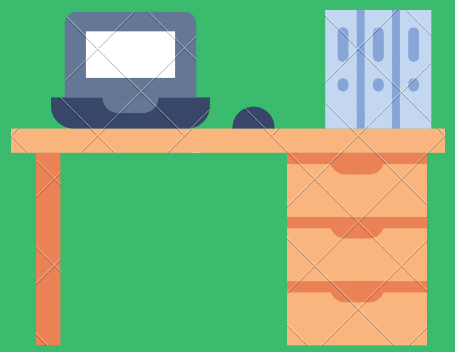
Design Overview


cafe & lounge
recreation area
atrium
South Campus
North Campus
office space
main office space
main basement
percolation basin
edible agriculture
metro rail

Site Layout

Expected Water Demand

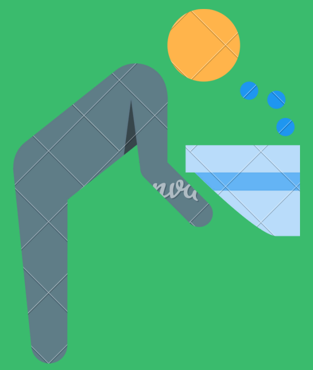
office space



showers

cafe

recreation area



Responsible Water Use

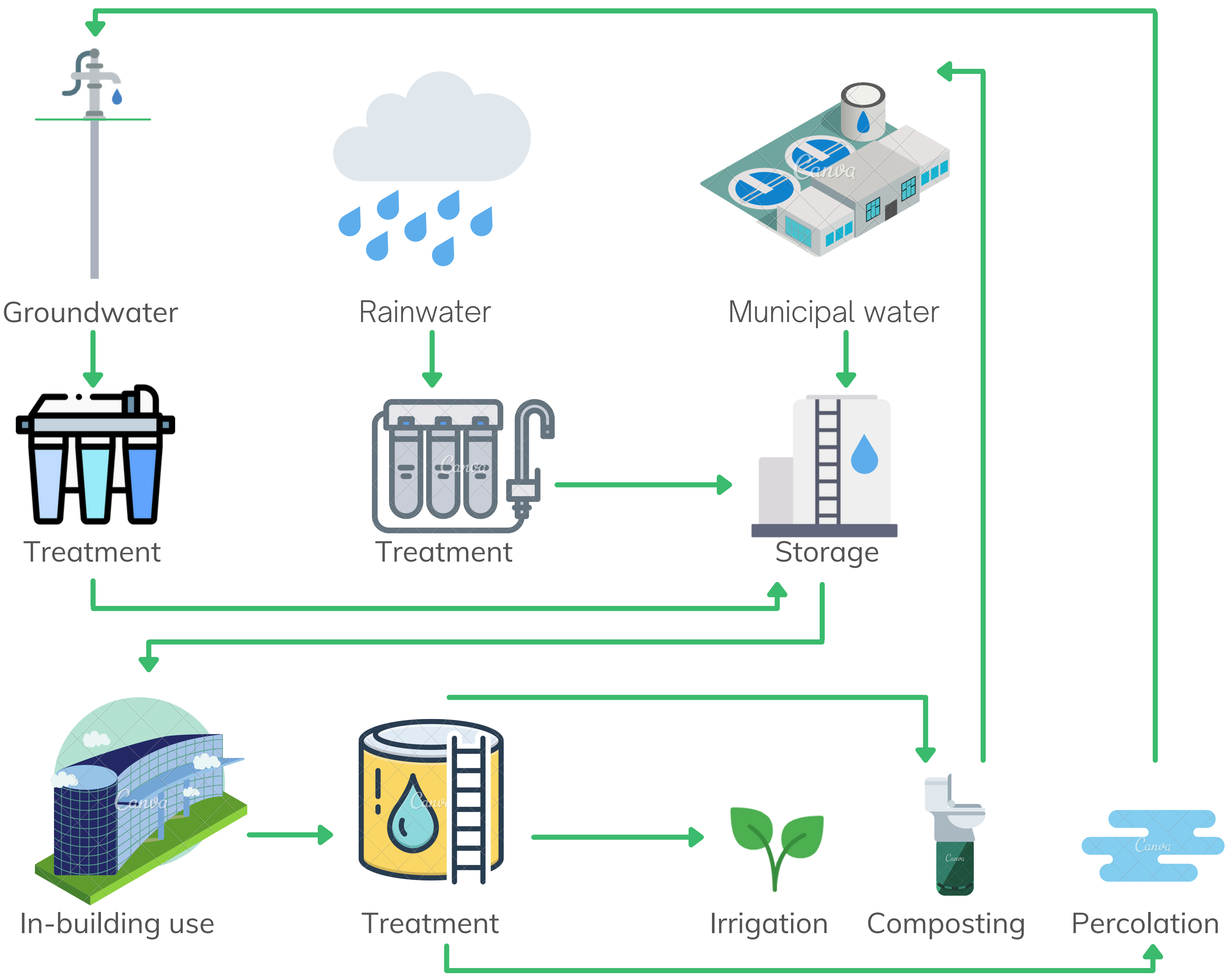
Must use 50% less water than baseline building

~0.7 million gallons annually

compare with industry average of ~1.5 million gallons

Water Strategy

- Rainwater to potable
  - Supplement with groundwater
  - Connected to the municipal line for emergencies
- Greywater Reuse
  - Indirect recharge groundwater well
  - Composting toilets



Rainwater

rain from roof to potable use

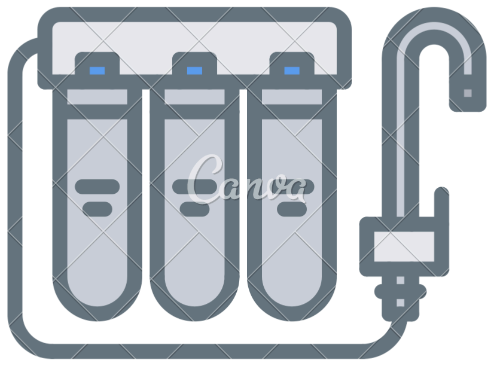
1

rainwater collection

3980 gpd

2

EPA Drinking Water Regulations



Filtration + Disinfection

Maelstrom Rainwater Filter

Harmsco Cartridge (LT2 Filter) - HC/40-LT2

3

potable storage

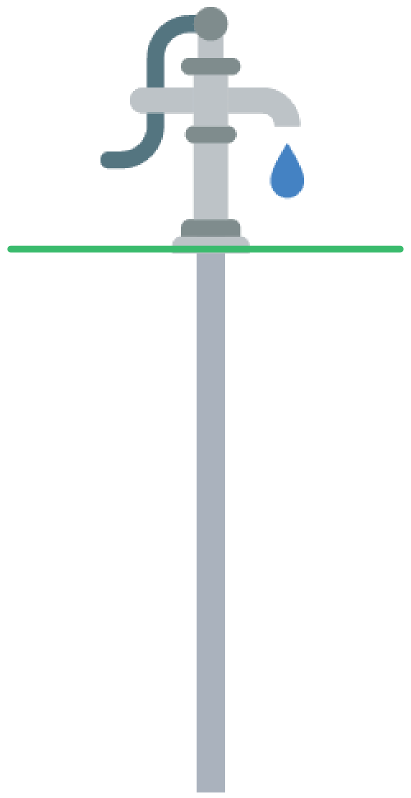
for building use

Groundwater

drought-backup well water

1

groundwater well



3980 gpd

2

EPA Drink Water Regulations

Reverse Osmosis + Disinfection

MRO 5400-4-LP

3

potable storage

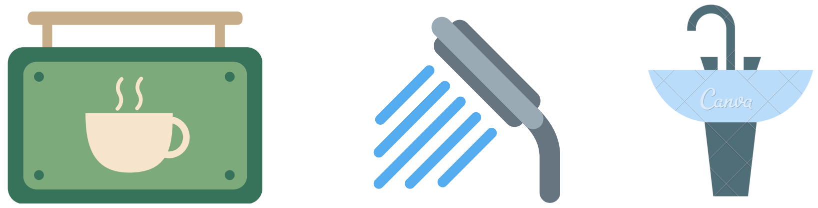
for building use

Grey Water

recycling 100% of water on-site

1

greywater captured



3970 gpd

2

title 22 standards

Membrane Bioreactor + Disinfection

ZeeWeed 500S membrane

3

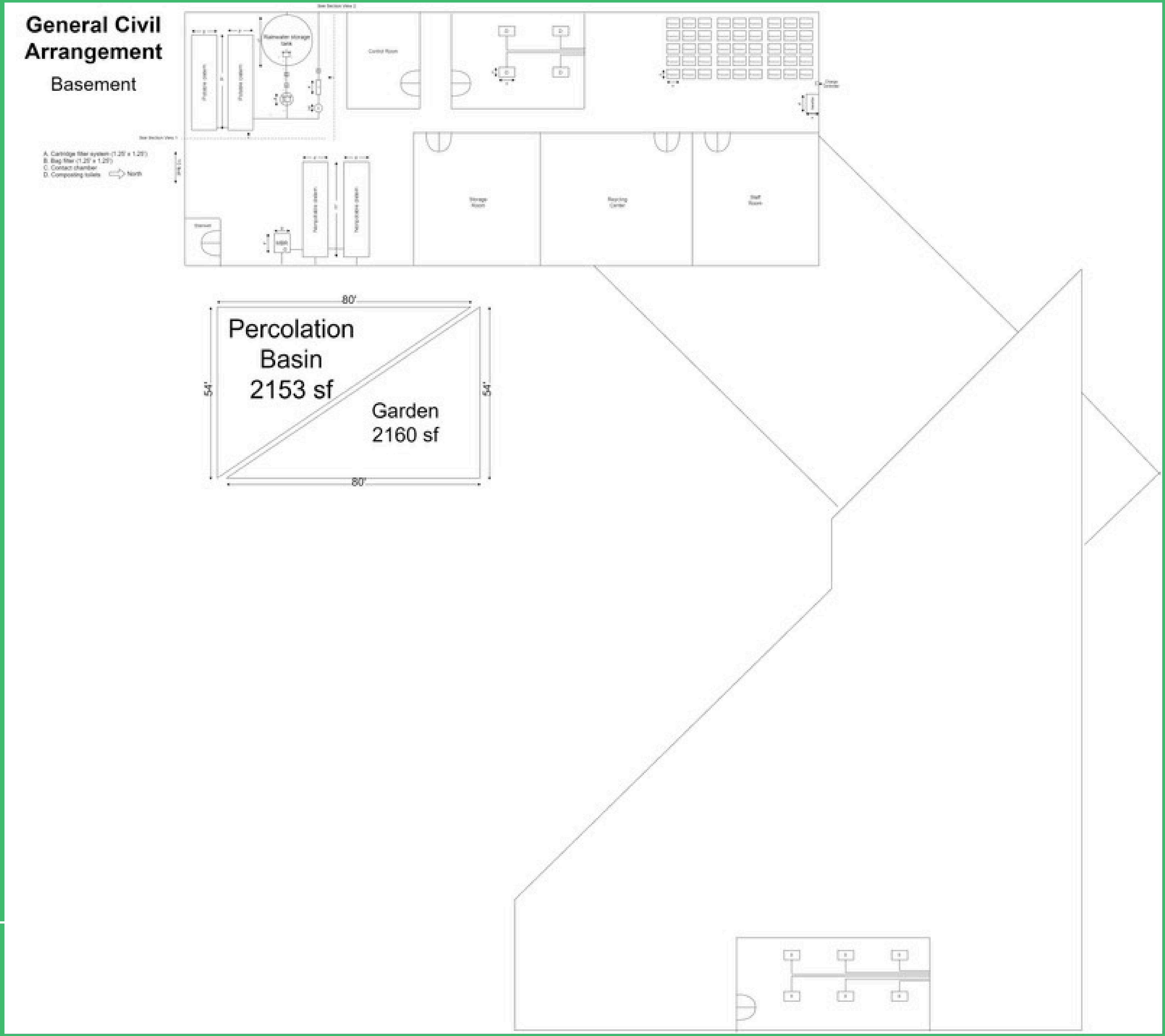
greywater uses

irrigation, toilets, infiltration

Overall Site Layout

The basements hold our treatment trains, power packs, and composting tanks.

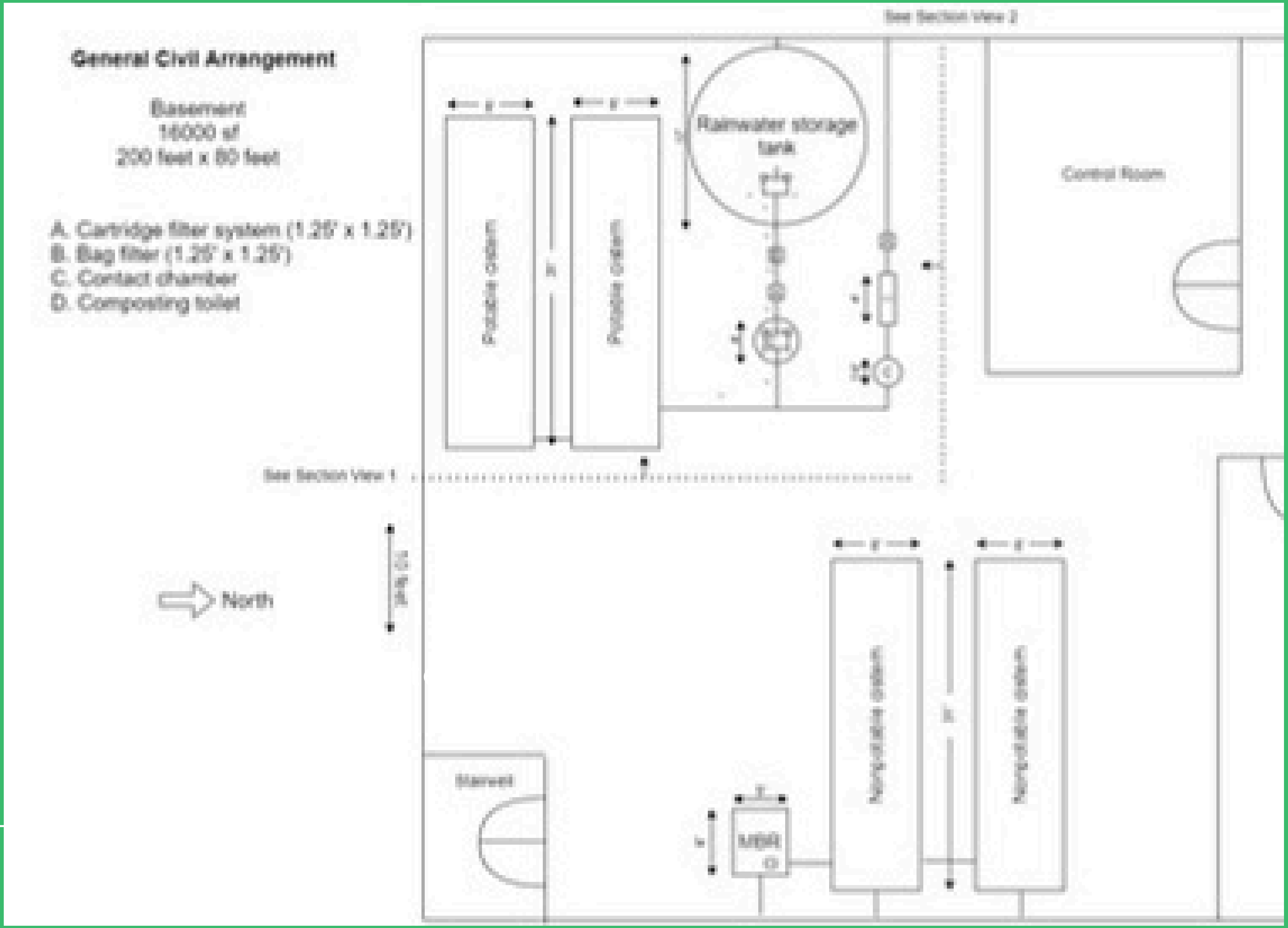
Extra space is used as storage room, recycling center, and staff room.



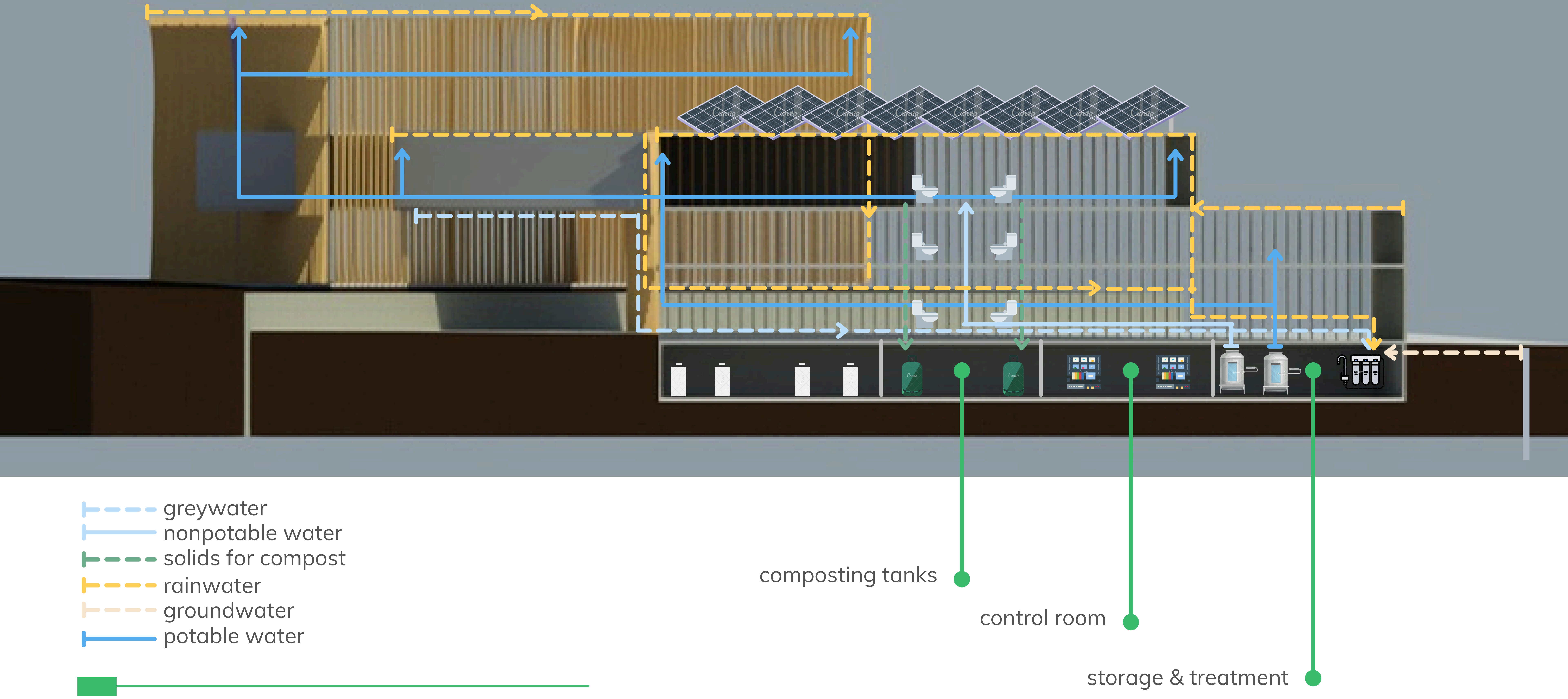
OVERALL SITE LAYOUT - BASEMENT LEVEL

Water System Layout

Overhead view of water treatment trains located in main basement



MAIN BASEMENT - TREATMENT SECTION



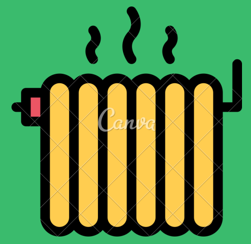
WESTERN SECTIONAL VIEW - WATER

Expected Energy Demand

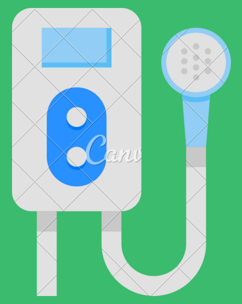
lighting*

office equipment

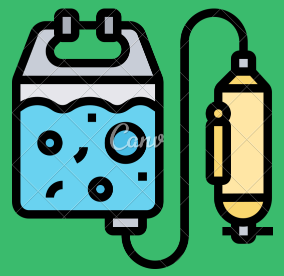
space heating*



hot water heating



water treatment*



ventilation

+ emergency storage for 1 week

Energy and Carbon Reduction

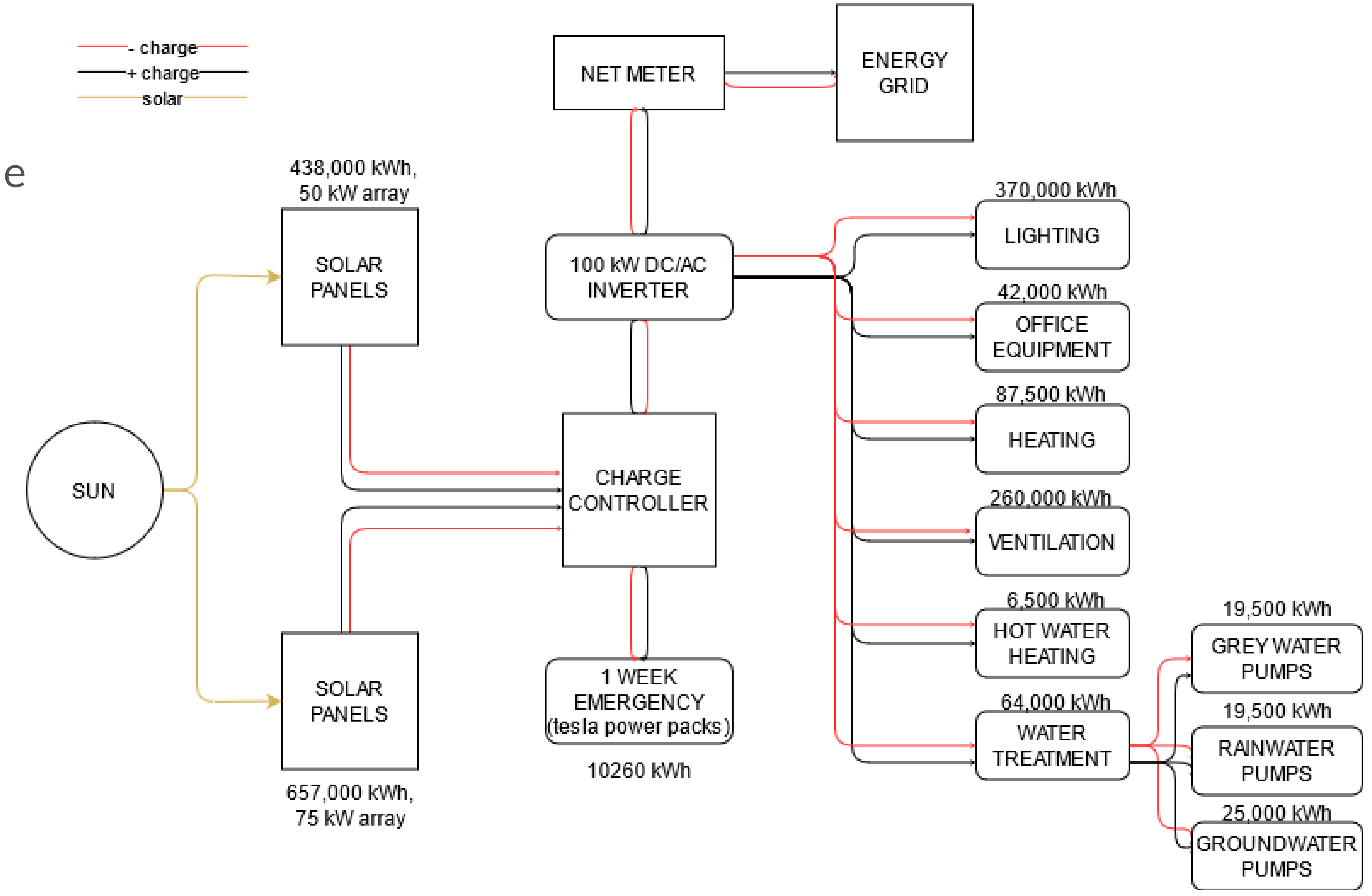
Must use 70% less energy than baseline building

~0.9 million kWh annually

compare with industry average of ~3 million kWh

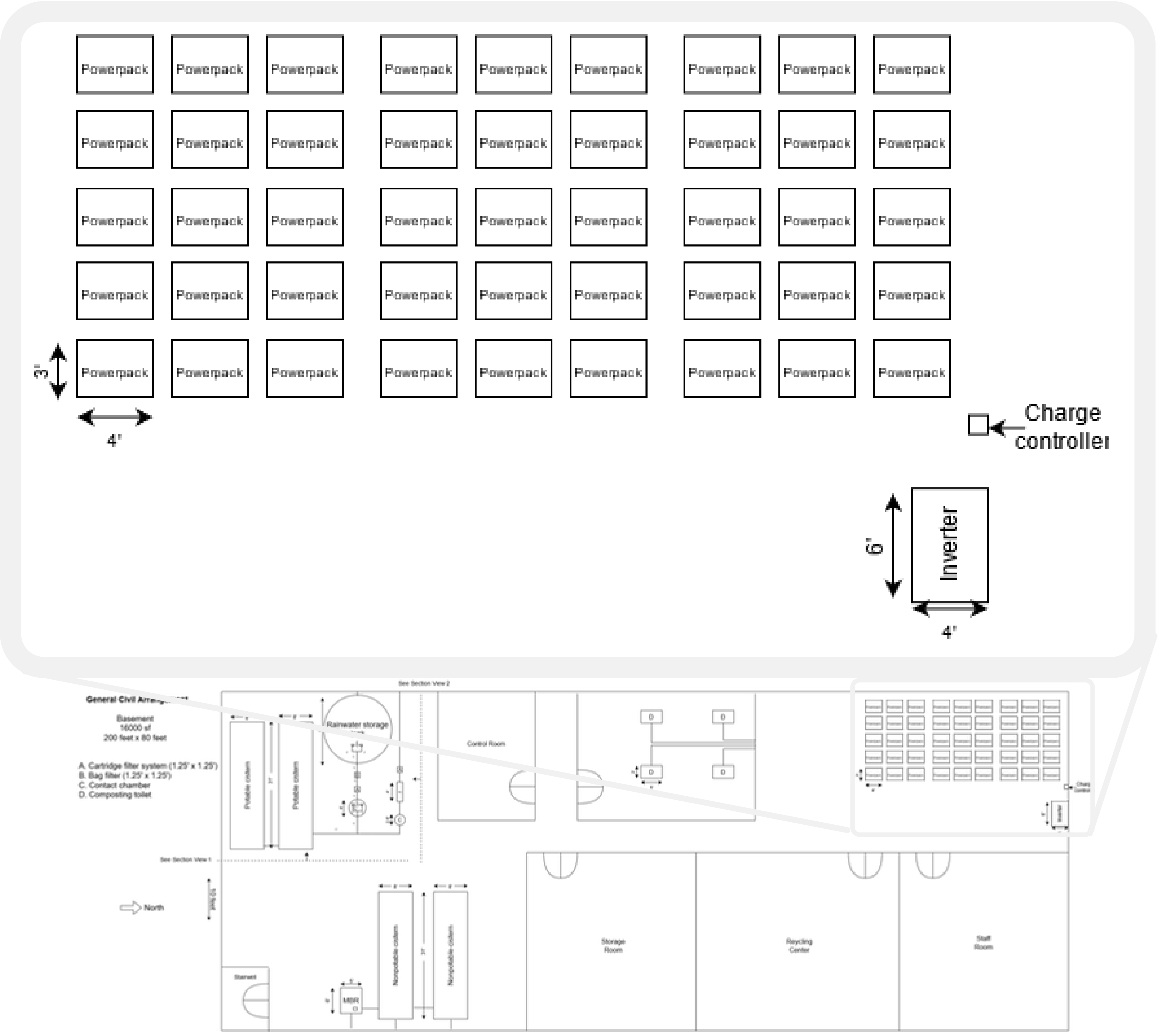
Energy Strategy

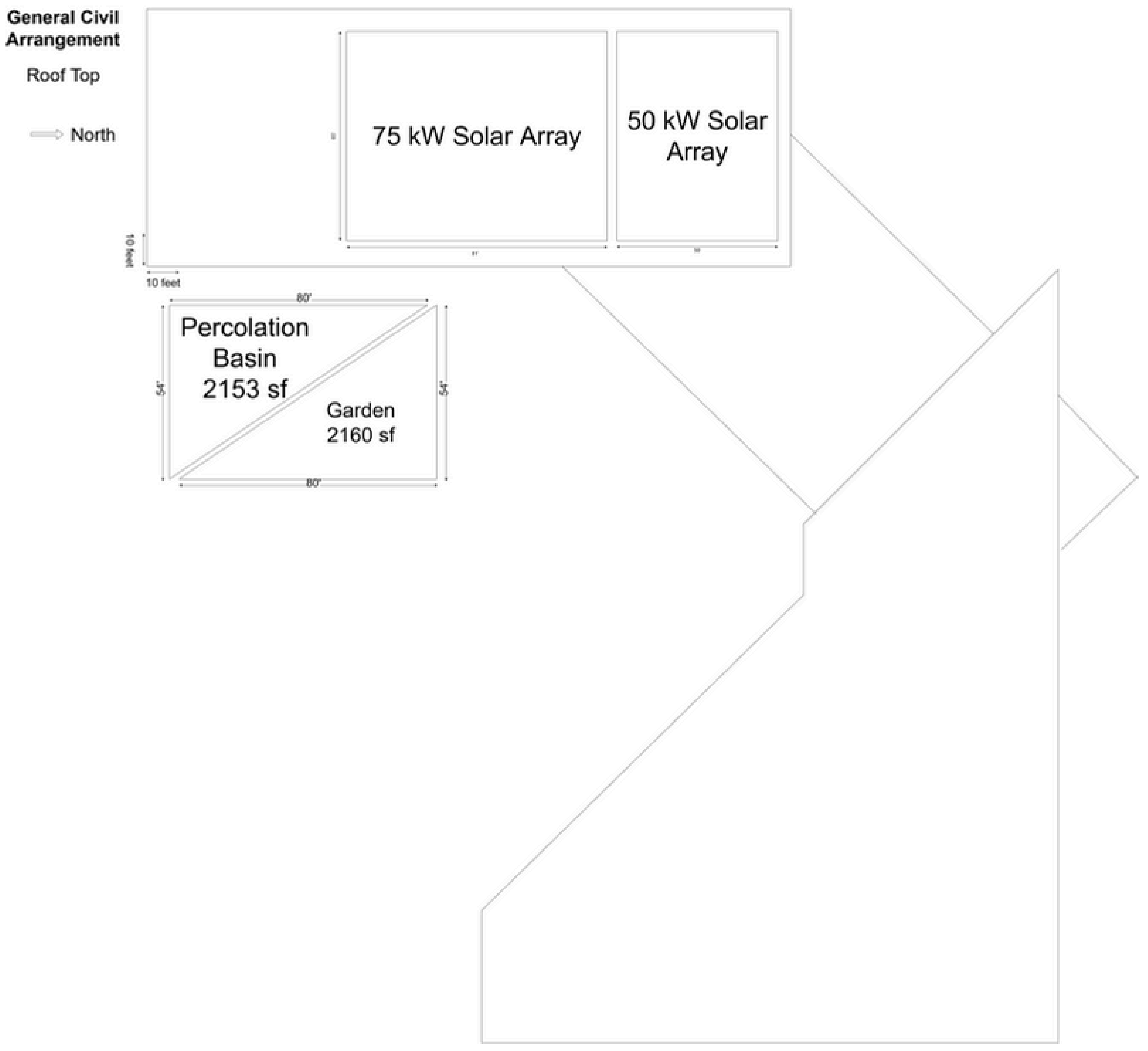
- 100% renewable energy generated on-site
- Two independent solar arrays
- 45 Tesla Powerpacks
- Connection to main-line
    - sell excess electricity
    - draw energy in case of emergency



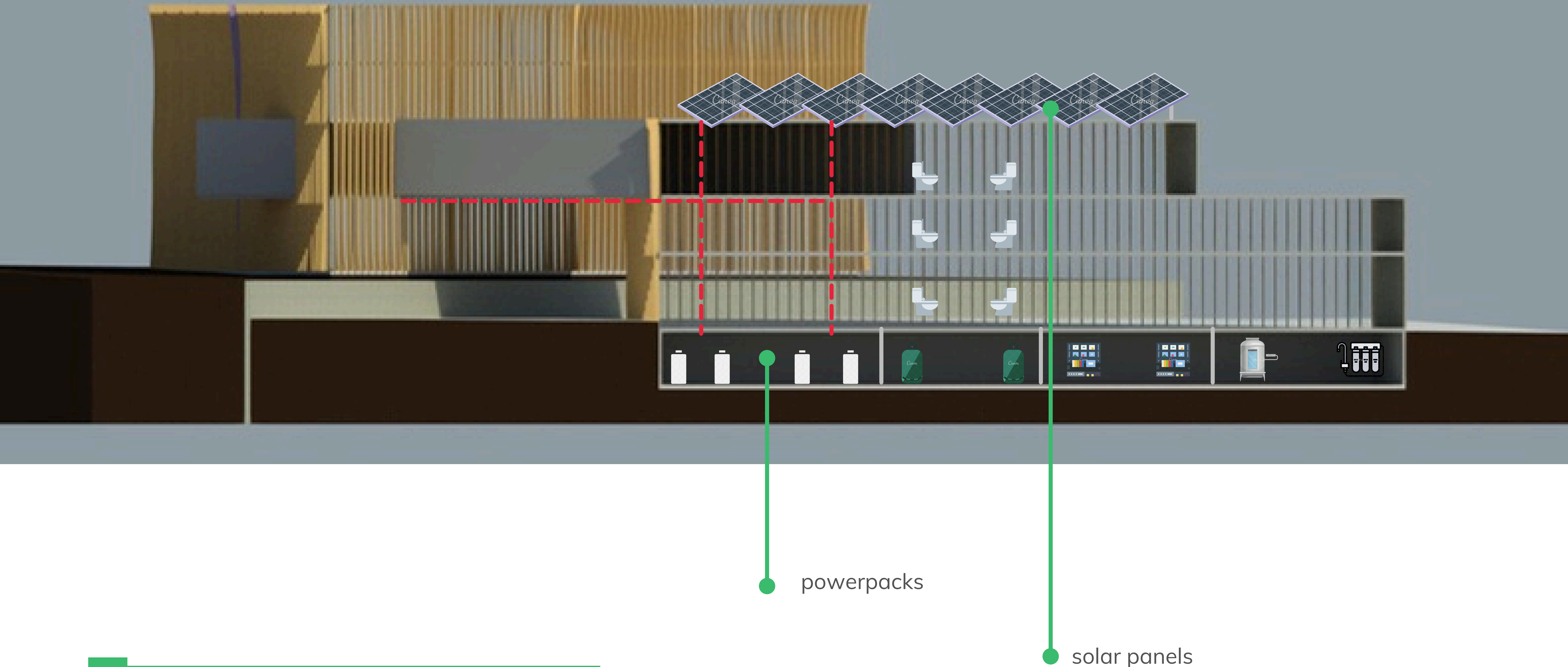
Net Positive Carbon

Must supply 105% of energy needs through on-site renewable energy





Energy System Layout



WESTERN SECTIONAL VIEW - ENERGY

Cost - Water

Baseline vs Living Building

Capital cost and operations + maintenance cost were summed over the course of 30 years and averaged to find annual cost.

Living Building

Annual Cost	$/Gallon	$/Acre-Foot
475,205	0.63	204,493

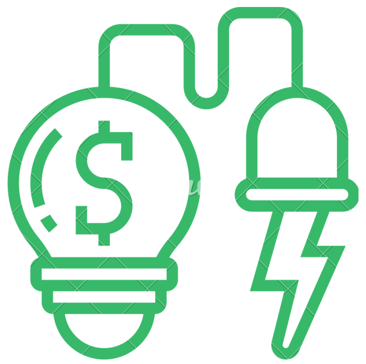
Baseline

Annual Cost	$/Gallon	$/Acre-Foot
119,653	0.002	690.89

Cost - Energy

Baseline vs Living Building

Capital cost and operations + maintenance cost were summed over the course of 30 years and averaged to find annual cost.



Living Building

Annual Cost

1,075,320

$/kWh

1.18

Baseline

Annual Cost

502,336

$/kWh

0.165

Cost Comparison & Recommendation

$1,550,524

LIVING BUILDING COST PER YEAR

$621,989

BASELINE COST PER YEAR

Despite the cost difference, we support embracing most aspects of the Living Building Challenge

- Cost can be heavily reduced by using fewer lithium-ion batteries
- Ecological & social equity aspects of the LBC are strong

Alternative Option

$656,164

LBC WITH 1 DAY'S WORTH OF BATTERIES

$621,989

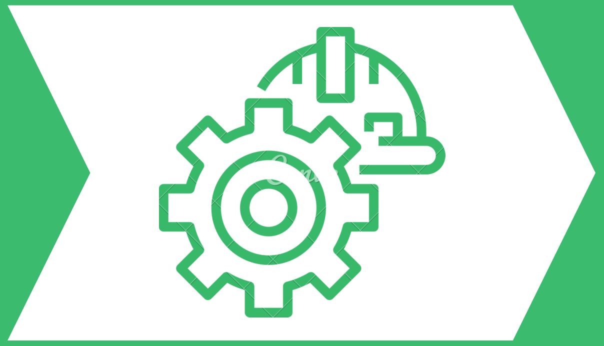
BASELINE COST PER YEAR

In order to strike a balance between sustainability and cost efficiency:

- Batteries reduced to 1 day's worth storage
- Emergency electricity supplied by the power grid

Performance Guarantee

1 - Construction



Project construction and systems built

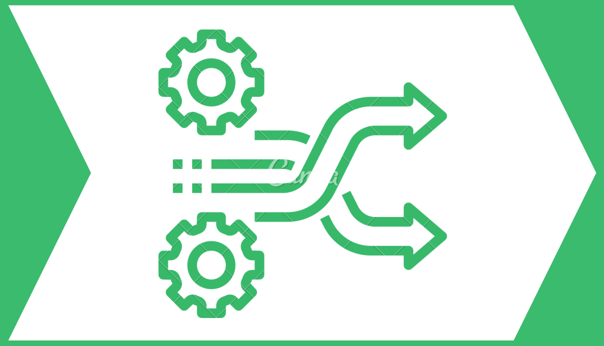
2 - Testing

Two-week testing trial with water quality sampling

3 - Evaluation

Evaluate performance over two week period & modifications needed

4 - Modifications



Modify designs & test for 1 week period

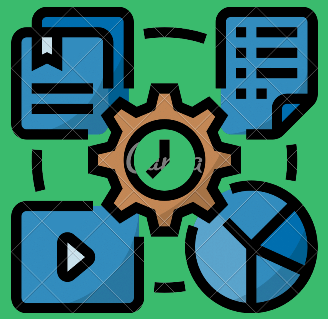
Comments on Collabration

LEVEL OF COMPLEXITY

Determining the scope and expanse of the project
(i.e. spacial distribution & building layout)

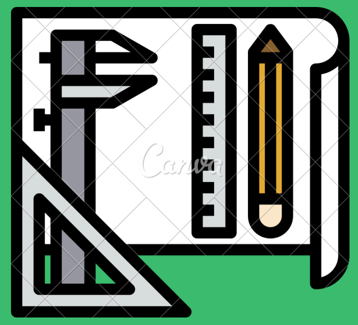
COMMUNICATION

Communicating consistently across multiple timezones
(i.e. zoom meetings, slack channels)



TIME MANAGEMENT

Scheduling out various project deliverables on estimates caused some delays in work
(i.e. demand calculations, BOD)



DESIGN CHALLENGES

Some processes required structural components of the project to be altered
(i.e. basements, atriums)

Thank you

Miles Hawkins

Energy & Cost Analyst

Serena Zhu

Mechanical & Energy

Marco Kleimans

Process Engineer

Jacob Totaro

PM/Environmental

Graham Drennan

Architecture

Ceasar Arreola

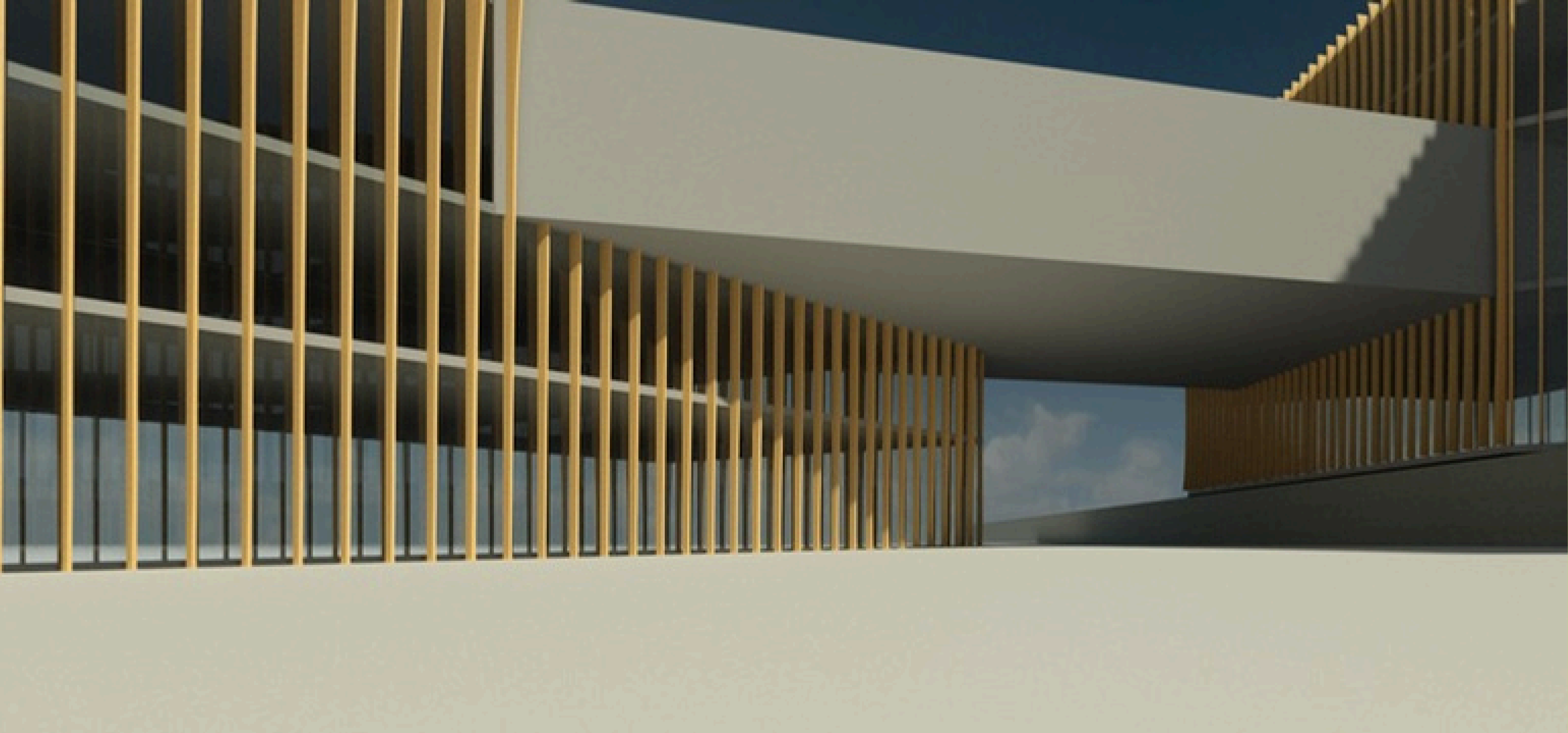
Foundation Engineer & Cost Analyst

Rushil Agarwal

Structural Engineer

Christopher Demas

PM/Structural



Questions?

Appendix

MJSM
Consulting

Spacial Distribution

Office Space	109,700 square feet
Office Space Per Capita	180 square feet/person
Coffee/Cafe	1,300 square feet
Grab and Go Food Stand	700 square feet
Recreation Center	16,000 square feet
Shower Rooms (x6)	600 square feet
Control room/Treatment Space	16000 square feet
Total Space	144,300 square feet
Visitors	40
Total maximum occupancy[2]	650 persons

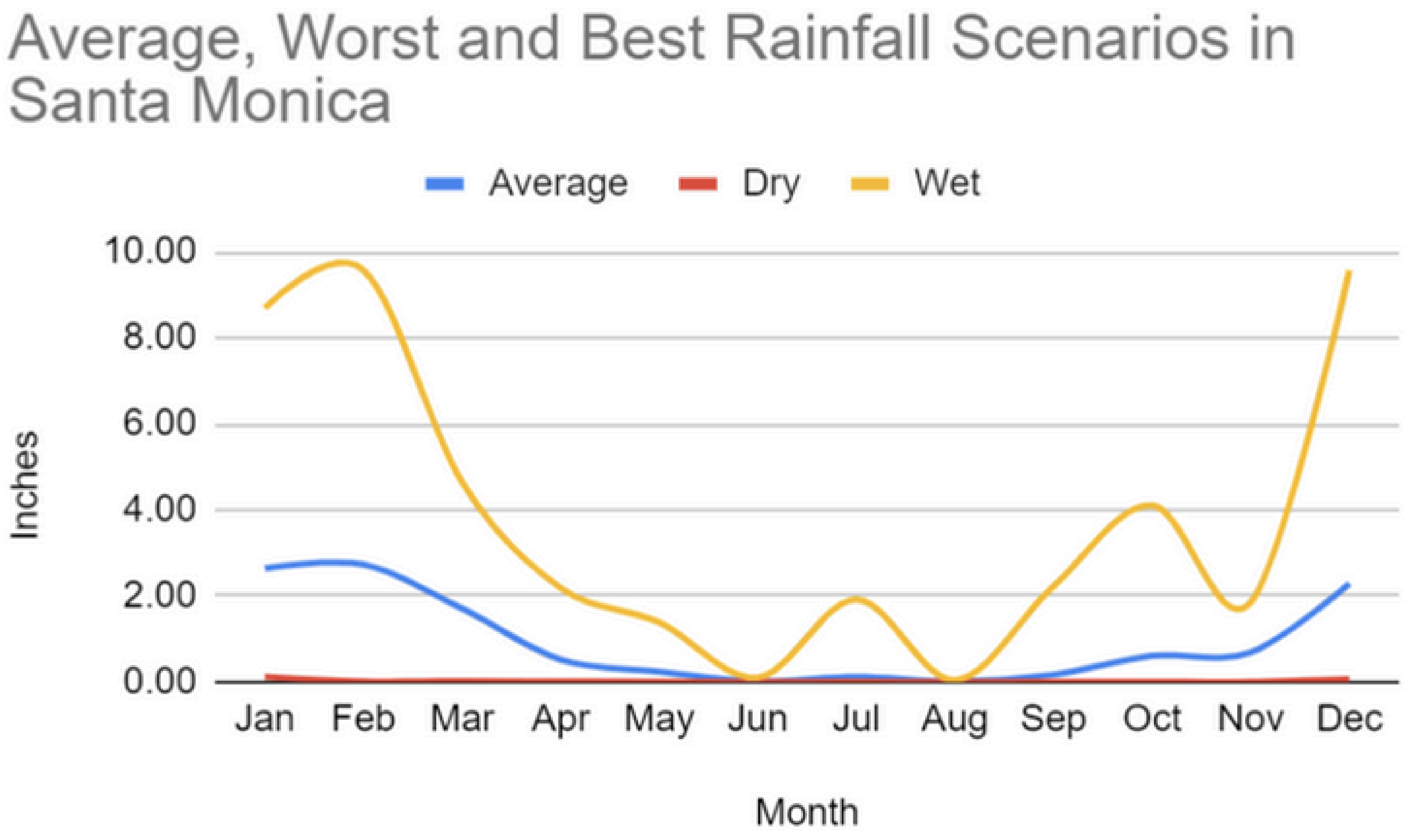
https://www.gsa.gov/cdnstatic/Workplace_Standards_Benchmark.pdf

Water Demand

Type of Space	Maximum Demand for LBC Project
Domestic/Restrooms (Office)	1473 gallons per day
Heating/Cooling (Office)	1115 gallons per day
Irrigation (Office)	876 gallons per day
Kitchen/Dishwashing (Office)	518 gallons per day
Total Office Space Demand	2,825 gallons per day
Showers	513 gallons per day
Coffee/Cafe (Starbucks)	520 gallons per day
Food Stand	125 gallons per day
Total Demand for LBC Building	3,982 gallons per day 121,117 gallons per month 1,453,400 gallons per year

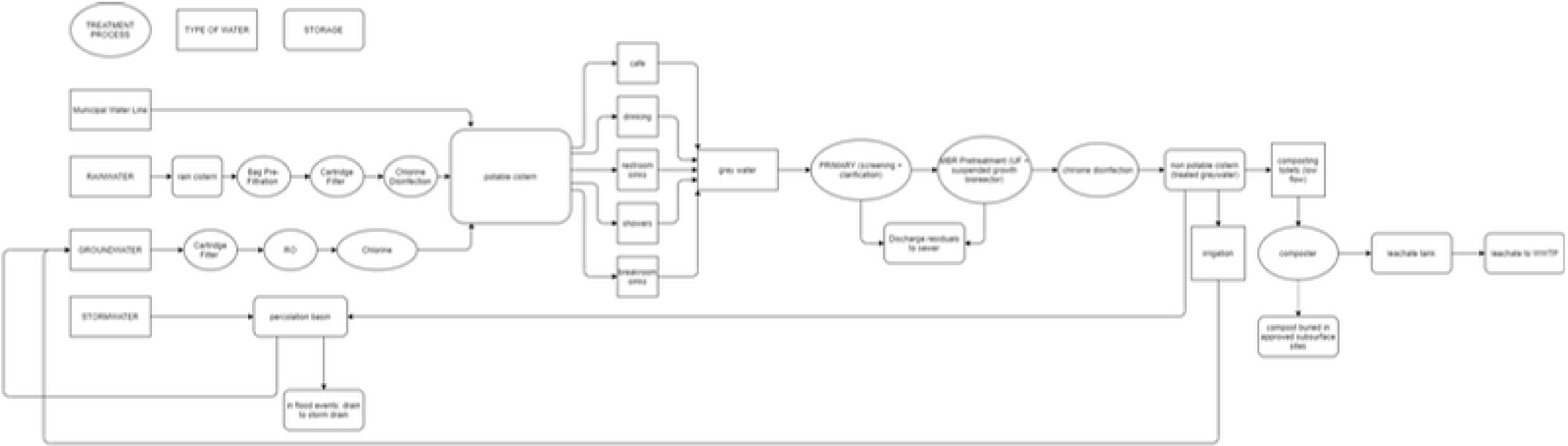
https://www.energy.gov/eere/femp/federal-water-use-indices

Rainfall



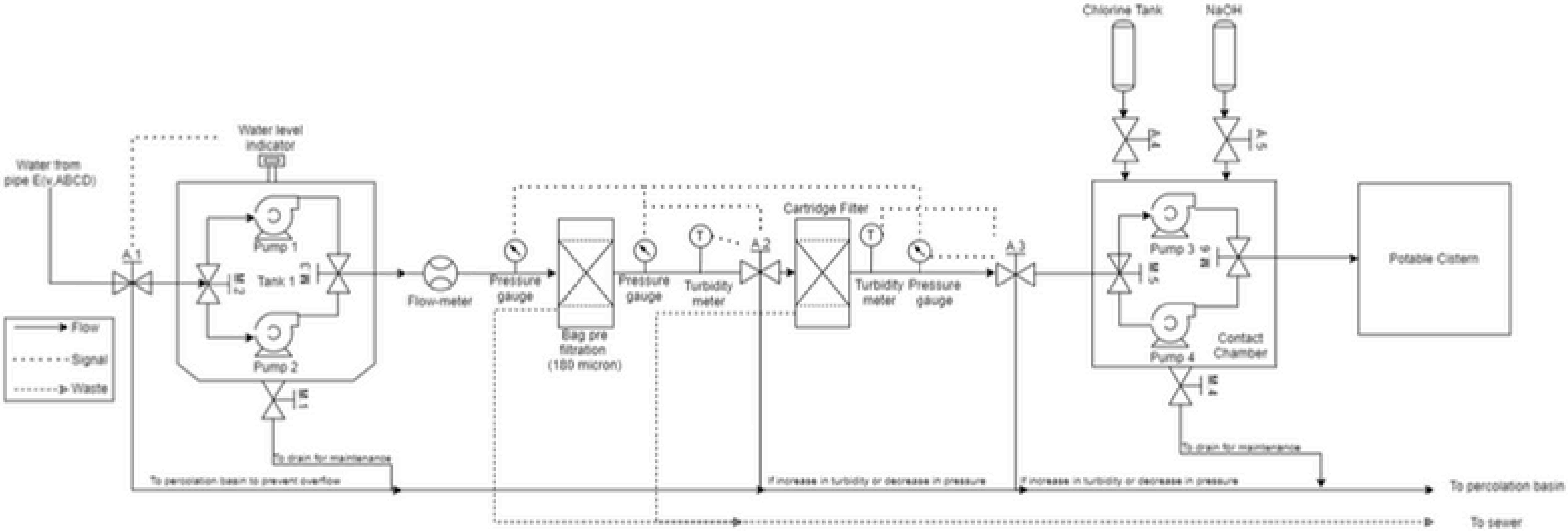
rainfall data from Western Regional Climate Center

Overall PFD

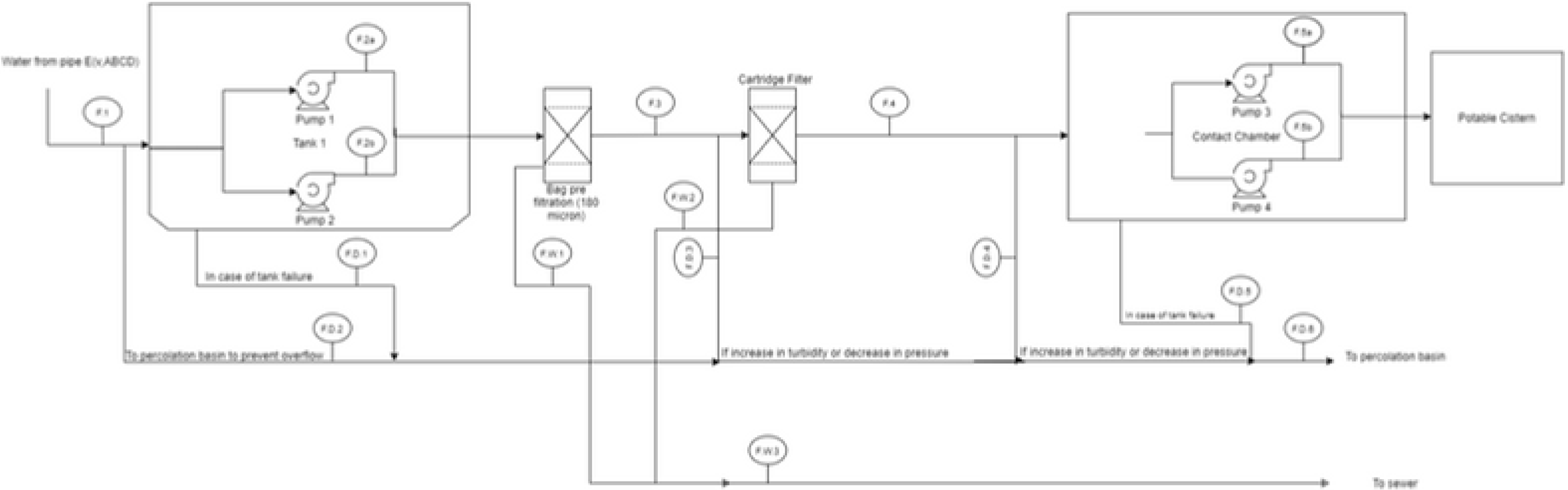


TREATMENT PROCESS
TYPE OF WATER
STORAGE
Municipal Water Line
RAINWATER
rain cistern
Bag Pre-Filtration
Cartridge Filter
Chlorine Disinfection
potable cistern
GROUNDWATER
Cartridge Filter
RO
Chlorine
STORMWATER
percolation basin
in flood events, drain to storm drain
cafe
drinking
showers
grey water
PRIMARY (screening + clarification)
MBR Pretreatment (UF + suspended growth bioreactor)
Discharge residuals to sewer
chlorine disinfection
non potable cistern (treated greywater)
irrigation
composting toilets (low flow)
composter
compost buried in approved subsurface sites
leachate tank
leachate to WWTP

PI&D Rainwater



Flow Balance Rainwater

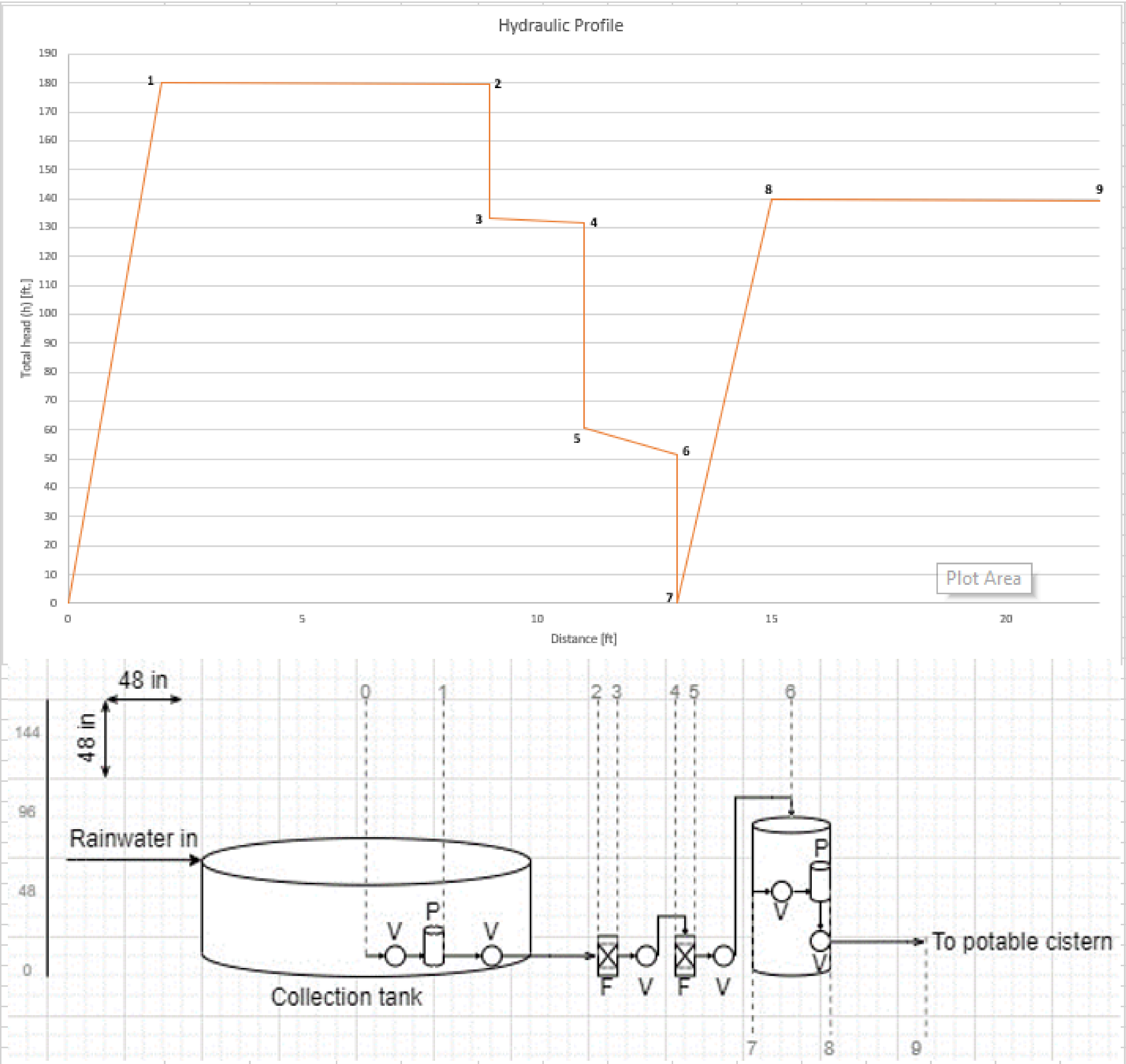


Primary flow								
Flow #	Units	F1	F.2a	F.2b	F.3	F.4	F.5a	F.5b
		Rainwater inflow	Tank 1 effluent - Pump 1	Tank 1 effluent - Pump 2	Bag filter effluent	Cartridge filter effluent	Contact chamber effluent - Pump 3	Contact chamber effluent - Pump 4
Flow	gpm	6.74236	5	5	4.95	4.9005	4.9	4.9
Comments		From design table	Pumps 1 and 2 will work one at a time (i.e. 5 gpm flow and not 10 gpm flow)		99% efficient	99% efficient	-	-

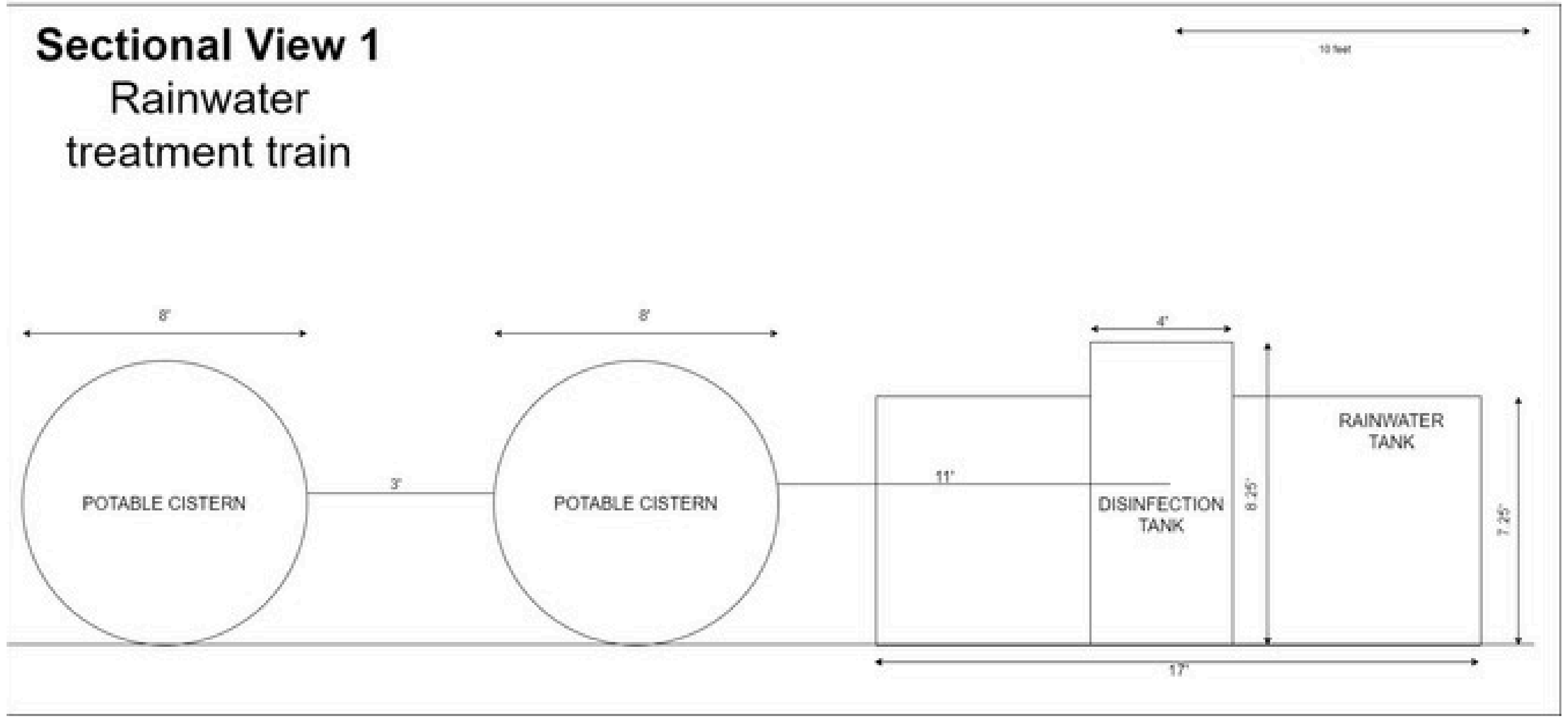
Diverted flow							
Flow #	Units	F.D.1	F.D.2	F.D.3	F.D.4	F.D.5	F.D.6
		Tank 1 effluent (overflow)	Tank 1 effluent (Failure)	Bag filter effluent (failure)	Cartridge filter effluent (failure)	Contact chamber effluent (failure)	Max to percolation basin
Flow	gpm	6.74236	0.5894	4.95	4.9005	0.411173	6.74236
Comments		max flow from rain being diverted	For a 2" pipe (no pump - gravity flow)	all bag filter flow being diverted	all cartridge filter flow being diverted	For a 2" pipe (no pump - gravity flow)	max possible flow

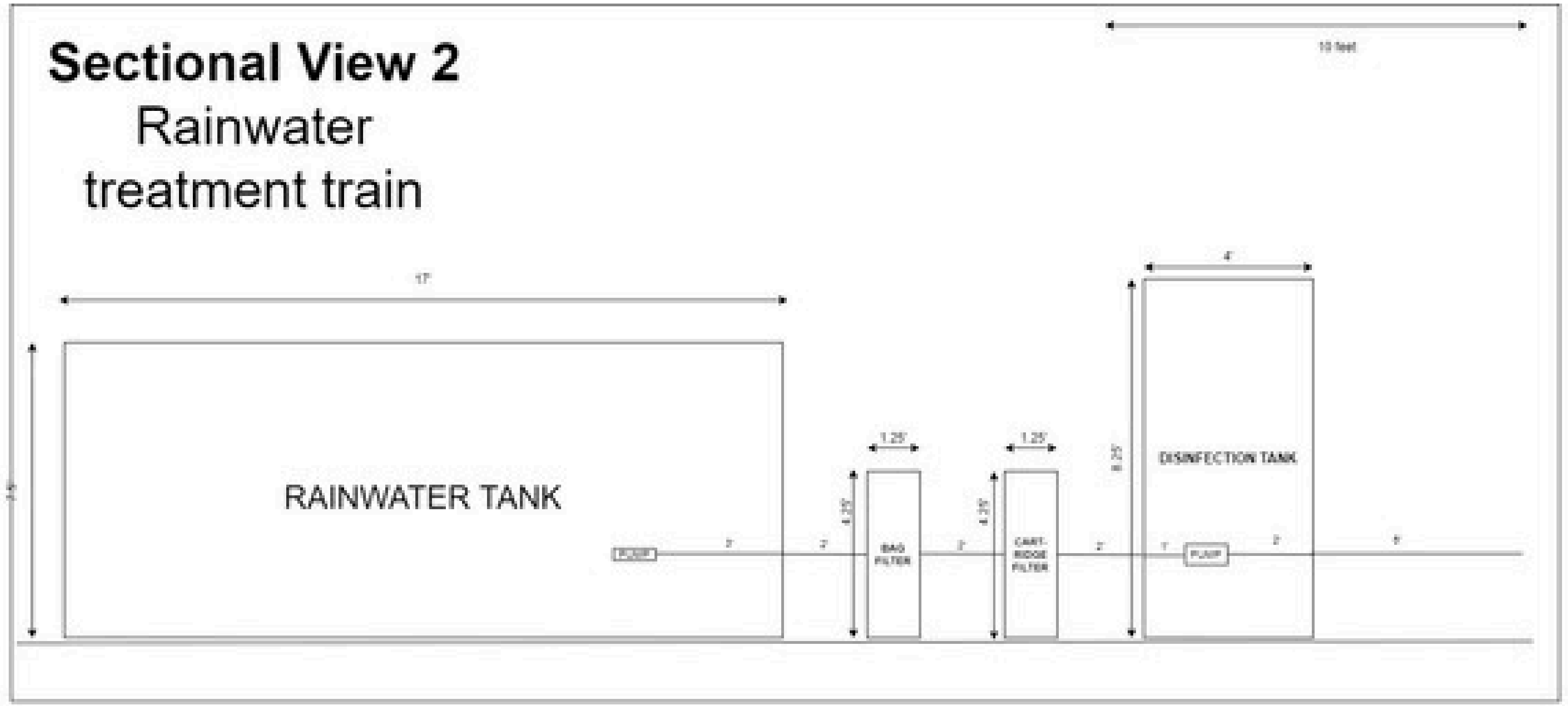
Waste flow				
Flow #	Units	F.W.1	F.W.2	F.W.3
		Waste effluent from bag filter	Waste effluent from cartridge filter	Combined sewer flow
Flow	gpm	0.05	0.0495	0.0995
Comments		-	-	-

Hydraulic Profile Rainwater

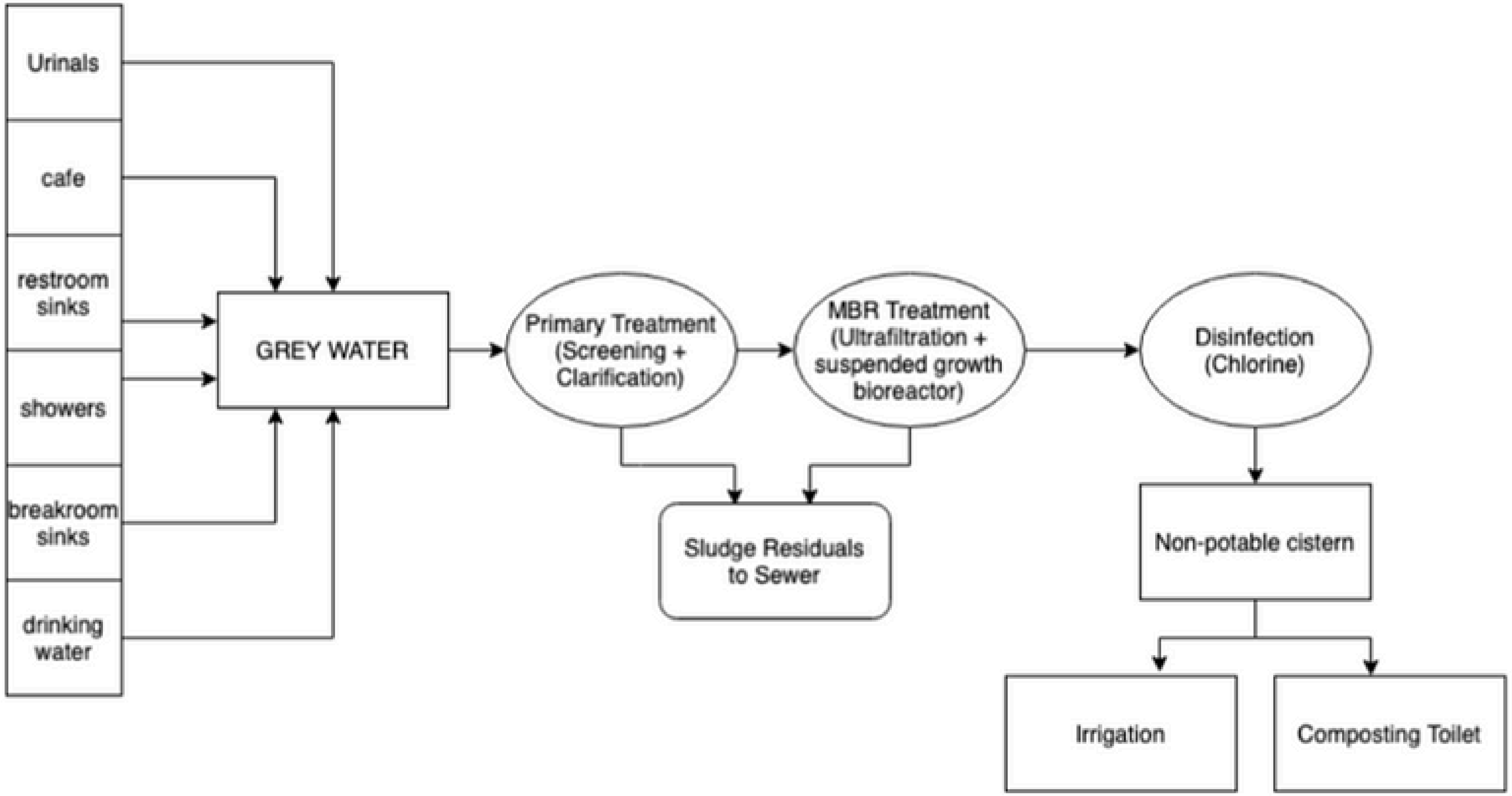


Rainwater sectional views





Grey Water Treatment Flow



Ground Water Treatment Flow