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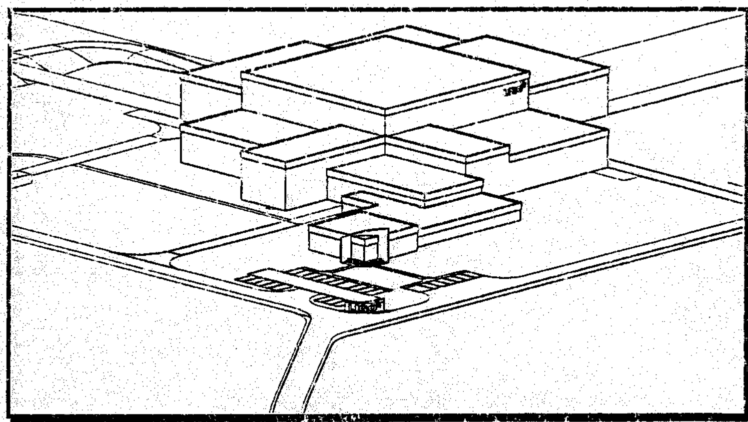

Final Design Configuration Control Document

July 10, 1995

LIGO
Laser Interferometer Gravity Wave Observatory
California Institute of Technology
The Ralph M. Parsons Company
Contract Number: PP150969

LIGO Document ______

CDRL Number 07

DRD Number 03

APPROVAL STATUS

YES NO NOT REQUIRED

Project Manager, Parsons

Technical Representative, Caltech

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1. Scope

The purpose of this document is to establish baseline design criteria for the Laser Interferometer Gravitational-Wave Observatory (LIGO) Facility Design. The baseline design criteria are developed from:

- Appendix A, B, and C of the LIGO Facility Request for Proposal No. YM 193
- Exhibit I of the LIGO Vacuum Equipment Request for Proposal No. MH 178
- Tiger Team Meetings
- Comments on previously submitted drafts of this document
- 90% Concept Design Report
- Facility and Beam Tube Enclosure Trade Studies
- Caltech and Parsons Technical Interchanges
- Our understanding of LIGO Project needs
- Industry standard design and construction practices that will meet or exceed these needs

This document serves as Facility design criteria from which the configuration of the Facility will evolve. As it evolves, this document will be updated. This document will continue to be the source for configuration control information for the direction of the design process. It is also the baseline for the design effort.

By reference, criteria provided in Appendix A, B, and C of the LIGO Facility Request for Proposal Number YM 193, and Exhibit I (LIGO Document 1100003) of the LIGO Vacuum Equipment Request for Proposal Number MH 178 constitute an element of this document and are therefore considered an element of the Facility's controlled design configuration. Concept strawman design approaches presented in these RFPs are not an element of the controlled design configuration; however, the layouts of the Vacuum Equipment in the LVEA and VEAs are considered a controlled design configuration.

This document will explain the concept design approach for the Hanford Site only. Occasional references are made to the Livingston Site, but only to establish some frame of reference, and to establish a general baseline for that Site also.

2. Facility Overview

The LIGO project is a pioneering effort to design and construct a novel scientific Facility -- a gravitational-wave observatory -- that will open a new observational window on the universe.

LIGO will consist of two observatory facilities. One will be located at Hanford, Washington, and the other at Livingston, Louisiana. These facilities will incorporate L-shaped vacuum systems with arms of 4 km length. The vacuum systems (by Others) will house laser interferometer detectors sensitive to gravitational waves generated by astrophysical sources. Initial detector sensitivity will detect strains as small as 10^{-22}. Correlation of data from interferometers at the two Sites will allow identification of gravitational waves, their sources and origin in space. LIGO will become the first part of a planned worldwide network of gravitational-wave detectors coordinated to operate as a single observatory complex. Current plans are to begin observatory operations by the year 2000.

Constructed facilities at each Site include the main Corner Station, with the large Laser and Vacuum Equipment Area (LVEA), End, and Mid Stations (Mid-Point Pumping Station at Livingston) on each Beam Tube arm, and a Site service area with chillers, pumps, water tank, and other ancillary maintenance components. Building work includes, but is not limited to, earth work, power distribution, lighting, security systems, fire protection, communications, control system, access platforms, cleanrooms, cranes, heating ventilating and air conditioning, and cable raceways. Each Site will have two Beam Tube Enclosure structures, each 4 km long. Sitework for the virgin Sites includes Site grading, drainage, roads, parking, landscaping, water supply developed from wells, sanitary facilities, waste water treatment and disposal and power distribution from area utilities.

Facility design will address special building requirements for the Laser and Vacuum Equipment Area located at the Corner Station, and Vacuum Equipment Area at the Mid, and End Stations.

- Vibration isolation and reduction is required in order that transmitted vibration energy is as low as possible given the size and budgetary constraints. Both Sites were selected based on their low ambient background noise and vibration levels. This requires seismic mass type foundations for critical scientific equipment and separate foundations and remote locations for vibration producing equipment and occupancy.
- Laser and vacuum equipment will be located in a large open space of high volume and provided with cleanroom type finishes but serviced by conventional air changes and quality.
- Smaller support areas for scientific equipment will require cleanroom conditions to Class 5000 or better.
- The laser interferometer detector is sensitive to EMI effects and will require special design for power, lighting, and control circuits to minimize disturbances.

3. Systems Provided by Others

These systems are designed, provided, and installed by Others and, in general, consist of the following items

3.1 Beam Tube System

- Beam Tube Segments
- Expansion Joints
- Pumping Ports
- Baffles (Internal to Beam Tube)
- Beam Tube Support and Leveling Subsystem
- Bakeout Subsystem
- GPS Positioning and Alignment Monitoring Subsystem

3.2 Vacuum Equipment System

- Vacuum Chamber Subsystem
- Pumping Subsystem
- Valve Subsystem
- Vent and Purge Subsystem
- Bakeout Subsystem
- Monitor and Control Subsystem

3.3 Detector System

- Interferometers
  - Lasers
  - Optics
  - Coarse Alignment
  - Seismic Isolation
- Control and Data System
- Physics Monitoring
- Support Equipment

4. Growth and Flexibility

4.1 Laser and Vacuum Equipment Area

The vacuum equipment is of a modular design to facilitate phased expansion. The initial installation at Hanford will serve two interferometers but may be expandable to a total capacity of five by adding an additional LVEA mat foundation, extension of building envelope, and interferometers at the Corner Station. For purposes of this design and construction package, only Site space is provided for this future expansion. No design, foundations, structure, mechanical capacities, or infrastructure is required at this time for possible expansion of the Facility.

At Livingston, one interferometer is planned initially with capacity for an additional one by adding chambers and vacuum components at the End and Corner Stations. This expansion will be accommodated by the Facility with only moderate modifications which involve placement of second interferometer and hook-up to existing utilities (i.e., power, laser cooling, etc.).

Also both Sites will have provisions for future length extension of the Mode Cleaners. This provision amounts to a "stay clear zone" in the direction of the possible extension. No foundations, structure, mechanical capacities, or infrastructure is required at this time for this possible expansion of the Facility.

4.2 Operations Support Building

Operations will require expansion of the office and shop facilities at some future time. Initial construction should facilitate this expansion with minimum impact to the existing Facility. Temporary population surge at time of interferometer installation may be accommodated by adding temporary trailers in a designated area near the Operations Support Building (OSB).

5. Design Criteria and Interface Requirements

5.1 General Facility Requirements

A. Units of measurement are in English units.

B. Various Federal specifications will be used as the Guideline Construction Specification.

5.1.1 Fabrication and Construction Tolerances

The A-E will provide, in the drawings and specifications, all tolerances for fabrication, construction, and installation.

5.1.1.1 Structural Steel

Minimum tolerances for structural steel construction will be per the AISC "Code of Standard Practice for Steel Buildings and Bridges".

5.1.1.2 Concrete

Minimum tolerances for concrete construction and materials will be per ACI 117, "Standard Specification for Tolerances for Concrete Structures and Materials".

5.1.1.3 Installed Equipment

Tolerances for equipment interfaces specified by the A-E will not exceed the manufacturer's tolerance requirements.

5.1.2 Service Life

5.1.2.1 Facility Design Life

Facility design will be for a 30 year service life.

5.1.2.2 Systems and Equipment Design Life

Operating systems and equipment design will be for a 20 year service life.

5.1.3 Construction Category

The LIGO project is categorized as permanent construction, in accordance with the UBC and SBC.

5.1.4 Occupancy

Each LIGO project Site will be designed for a maximum shift population of 40 people. The breakdown of anticipated personnel and their classification is as follows:

Staff	Quantity
Technician and/or Operators	10
Technician Specialists	3
Engineers	3
Site Administration	2
Scientific Staff	3
Visiting Scientists	6
Interns and/or Visitors	9
Maintenance Personnel	4

Table 5.1-1 -- Staff List

5.1.5 Design

Design of the Facility will comply with the Industry Standards and Specifications referenced herein and good design principles. The Facility will be designed for, low risk, and ease of maintenance and operability.

5.1.6 Safety

Construction of the facilities will comply with OSHA- 29 CFR, and applicable local codes (e.g., Washington Institute of Safety and Health Administration (WISHA) at the Hanford Site).

5.1.7 Security

Security of the facilities will comply with good industrial practice. The major security effort will be to design for minimum potential intrusion into the Station buildings and Beam Tube Enclosures.

5.1.8 Material Selection

5.1.8.1 Flame Spread

All materials will be noncombustible or have a flame spread rating of 25 or less in accordance with ASTM E84.

5.1.8.2 Cleanliness/Contamination

Also see Section 5.4.9 for additional cleanroom interior design requirements.

A. Design will use non-corrosive and/or corrosion resistant material as required.

B. Exclude use of fraying or other material that could contribute to contamination in the LVEA and all other Cleanrooms.

C. Preclude ledges that may trap dirt and minimize oil leakage from mechanisms and mechanical equipment.

D. Consideration will be given to out-gassing and particle generation of the materials.

E. All materials will be compatible with the cleanliness requirements of the room's classification.

5.1.8.3 Material Compatibility

As a design goal, all material selections should be made to minimize Non Volatile Residue (NVR) deposition in the LVEA.

5.2 Civil

5.2.1 General Civil Requirements

Civil requirements include Site preparation and earthwork, hydrology and drainage, roads and paving, parking, utilities, wastewater treatment and other Site improvements. Area contours shall be provided by Caltech's surveying Consultant for each Site.

Careful attention will be paid to development of the Site to the special needs of LIGO and of the individual Site characteristics. Establishing and maintaining alignment are important considerations at both Sites.

Caltech's Consultant shall provide soil conditions and allowable design parameters.

5.2.2 Coordinate Control

5.2.2.1 Global and Local Coordinate Systems

At each Site there will be both a "Global Coordinate System", and five "Local Coordinate Systems". A Local Coordinate System will be established for each of the five Station Locations (i.e., Corner Station, 2 Mid Stations, and 2 End Stations). The Global Coordinate System (i.e., X_G, Y_G, Z_G) is dependent on the X_G, Y_G, Z_G system defined by the Beam Tube arms with the Z_G axis up.

Local coordinates (i.e., X_L, Y_L, Z_L) are determined by Z_L being plumb at each Station, and the X_L and Z_L axes are in the same vertical plane as the longitudinal axis of the respective Beam Tube and Z_G.

Note that even though the global and local coordinate systems share a common origin, the plane defined by X_L and Y_L will not lie in the same plane as the X_G and Y_G axes unless the Z_G axis is also plumb (i.e., normal to the surface of the Earth) at that origin. This means that over a distance of 4000 meters, the plane defined by X_L and Y_L will rotate about the Y_L axes by as much as 0.6214×10^{-3} radians.

5.2.2.2 Hanford

The intersection of the two centerlines of the property arms is located at latitude 46° 27' 18.5"N and longitude 119° 24' 27.1"W. The northwest arm is at a bearing of N36.8°W and the southwest arm is at a bearing of S53.2°W from the origin of the global coordinate system. For further coordinate and Site boundary information see Figure 5.2-1.

5.2.2.3 Livingston

The intersection of the two centerlines of the property arms is located at latitude 30° 33' 46.0"N and longitude 90° 46' 27.3"W. The southeast arm is at a bearing of S18°E and the southwest arm is at a bearing of S72°W from the origin of the global coordinate system. For further coordinate and Site boundary information see Figure 5.2-2.

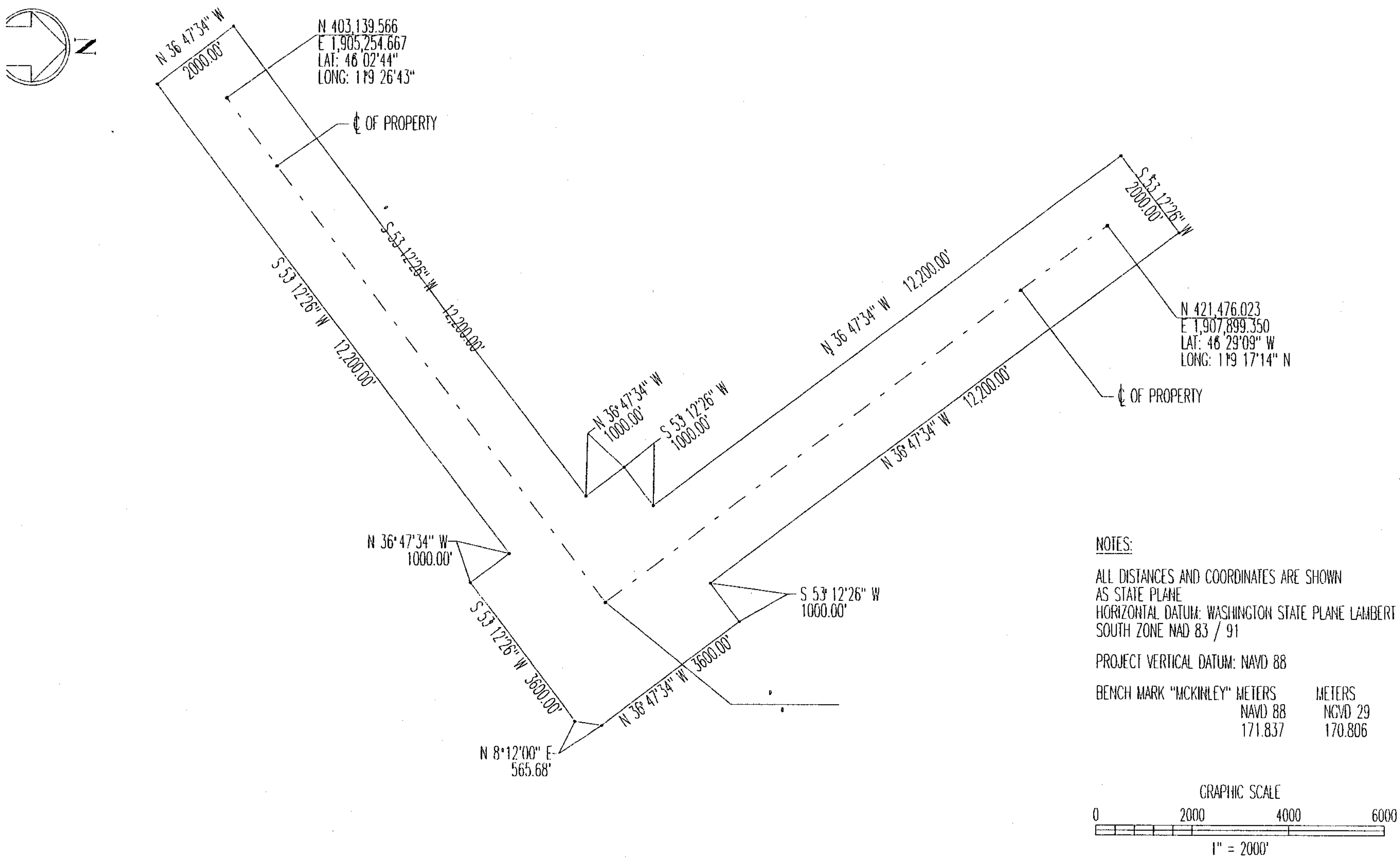

Figure 5.2-1 -- Hanford Property Boundaries (For Reference Only)

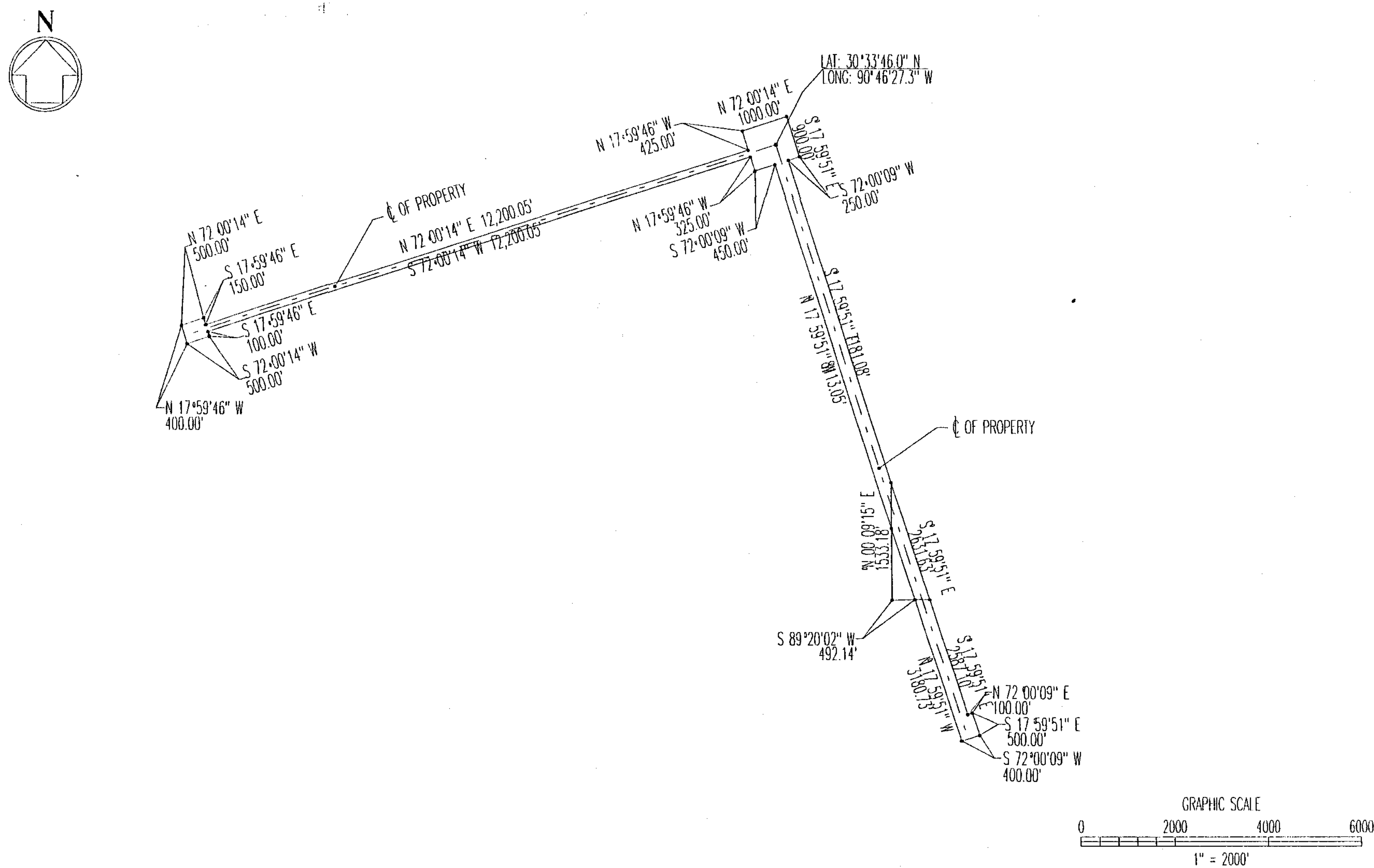

Figure 5.2-2 -- Livingston Property Boundaries (For Reference Only)

5.2.3 Site Preparation and Earthwork

Roads and graded areas shall be laid out to minimize environmental damage. Natural drainage patterns shall be maintained to the maximum extent possible. All Site areas will be graded away from buildings.

Earthwork slopes and grading shall be in accordance with the recommendations of the geotechnical reports and the following:

A. Cut slopes shall be 2:1 for Hanford and 2:1 (maximum) for Livingston Sites.

B. Fill slopes shall be 2:1 for Hanford and 3:1 for Livingston Sites.

C. Graded area pads shall be sloped 2% minimum for drainage.

D. At Livingston a minimum freeboard of 2 feet shall be used above the 100 year storm level.

E. The Beam Tube arm embankments form an "L" shape that will accommodate the LIGO interferometer arms. The two arms lie along two intersecting lines oriented perpendicular to one another, and define the plane of the interferometer. The Beam Tube arm embankments shall be flat graded with respect to this plane (as opposed to the normal grading practice that is relative to the earth's curvature). In order to accommodate local topography and minimize earthwork, the orientation of this plane may be modified by as much as $\pm 0.31 \times 10^{-3}$ radians with respect a tangent to the Earth's surface (i.e., a theoretical sphere) at the center of the square plane of the Beam Tube arms. The direction of the component of the interferometer plane normal which lies in the local horizontal plane (at the center of the square) can point in any compass direction.

F. The Beam Tube embankments shall be designed to minimize settlement.

5.2.4 Roads, Paving and Parking

The Site roads consist of a main access road to the facilities and a perimeter road around the facilities that also tie into the Beam Tube Enclosure service roads. The paved Beam Tube Enclosure service roads along each arm provide access to the Beam Tube at 780 foot (237.74 meter) intervals as well as access to the End and Mid Stations. For fire department access as well as access to the "backside" of the facilities during construction a road bridging at least one Beam Tube near the Corner Station is required.

Parking for permanent staff and visitors will be provided. A frost penetration depth of 24 inches maximum and 12 inches average shall be considered for the Hanford Site.

5.2.4.1 Roads

The road geometrics and cross-sectional design shall be in accordance with the following:

A. Roads shall be designed to positively drain with a minimum cross slope of 2% whenever possible.

B. Roads shall have a shoulder width of 4 feet (3 feet for Beam Tube service roads) minimum with a cross slope of 4%.

C. Roads shall be two-lanes where possible

D. Road side slopes shall generally be 2:1 for Hanford and 3:1 for Livingston.

E. Corner radii shall be no less than 35 feet.

F. Road centerline radius shall be as required for Site vehicles and construction equipment and deliveries (i.e. Beam Tube segments)

G. Road profile grades shall not exceed 6% whenever possible.

5.2.4.2 Paving

Paving design for the Facility roads and parking areas shall be in accordance with the following:

A. The pavements shall be designed to provide all weather access.

B. All access and service roads shall be flexible pavement unless operational considerations dictate otherwise.

C. Axle loading for roads shall be AASHTO H-20.

D. California Bearing Ratio (CBR) value for pavement design shall be [per geotechnical reports]

E. Paving shall be as flat and smooth as possible. No speed bumps, manholes, lane divider bumps, grating, etc.

5.2.4.3 Parking

Parking spaces shall be provided and designed in accordance with the following:

A. Parking for the LVEA/OSB facilities (Corner Station) shall be for:

1. 40 employees (including maintenance vehicles)
2. 7 visitors
3. 2 handicapped
4. 1 bus

B. Parking for the End Station shall be for:

1. 5 employees (including maintenance vehicles)

C. Parking for the Mid Station shall be for:

1. 5 employees (including maintenance vehicles)

5.2.5 Site Drainage

All drainage systems shall be designed to properly drain all surface water that can cause damage to the facilities, property, and adjoining land. A storm frequency of 50 years will be used for the design of all drainage structures.

5.2.5.1 Ditches

Sheet drainage to open ditches will be used to the maximum extent possible. Ditch side slopes at Livingston shall be no steeper than 3:1 to facilitate mowing and minimize erosion where required. Primary ditch work at Hanford has already been accomplished with ditch slopes at 2:1.

5.2.5.2 Pipes

Pipes or closed conduits will be used for drainage when open ditches interfere with the intended use of the area.

5.2.5.3 Culverts

Culverts shall be provided under roads or the Beam Tube embankment and whenever the natural drainage pattern is interrupted. Culverts shall comply with the following requirements:

A. Minimum diameter = 12 inches

B. Minimum gradient = 1%

C. Alignment shall be in the direction of storm flow and as nearly perpendicular to roads, embankments or obstructions as possible

D. The preferred culvert material shall be reinforced concrete pipe or concrete box sections

5.2.6 Utilities

The domestic water supply and the sanitary sewer system for the Corner Station (LVEA/OSB) shall be designed for a total work force of 40 on day shift and 10 each on swing and graveyard shifts. Fifty gallons per person per day shall be used as a basis.

Water and sanitary sewer requirements for the Mid Stations and End Stations are 10 personnel (not concurrent with 40 at the Corner Station. The firewater system will be designed in accordance with Local requirements.