CALIFORNIA INSTITUTE OF TECHNOLOGY

CALTECH/MIT LASER INTERFEROMETER
GRAVITATIONAL WAVE OBSERVATORY PROJECT (LIGO)
102-33 E. BRIDGE LABORATORY
PASADENA, CALIFORNIA 91125

ROCHUS E. VOGT, DIRECTOR
Telephone (818) 356-3800
Fax (818) 304-9834

November 20, 1990

Dr. George Seielstad
National Radio Astronomy Observatory
P.O. Box 2
Green Bank, WV 24944

Dear George,

On October 12, 1990, the National Science Board approved an NSF recommendation for a site selection process, under which Caltech is to conduct a competitive, public solicitation of sites for the LIGO.

As a courtesy to those who have previously provided information or participated in earlier LIGO siting activities, we are furnishing a copy of the Site Solicitation Announcement, which has just been published in the Commerce Business Daily. In addition, I am enclosing, for your information, a brochure describing the LIGO project and a LIGO Fact Sheet.

Sincerely,

RV/bb

Enclosures

LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY (LIGO)

Site Solicitation Announcement

The California Institute of Technology (Caltech) solicits proposals from interested parties who will provide land on which to build and operate the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO will be a national facility, open to the scientific community for research at the frontiers of physics and astronomy. A proposal by a team of scientists at Caltech and the Massachusetts Institute of Technology (MIT) to develop and construct the LIGO has been approved by the National Science Board (NSB), and construction and operation of LIGO are to be funded by the National Science Foundation (NSF). The NSB has authorized the LIGO Project to conduct a public search for two suitable sites in the U.S. to accommodate the LIGO facilities. The LIGO Project intends to evaluate all sites proposed as a result of this solicitation in order to identify the best available locations for this unique national facility. As part of this process, the LIGO Project may contact federal, state or local governmental organizations and include consideration of available land under their control and management.

Construction of the LIGO facilities ($\sim$ \$200M) is expected to start in FY 1992, to be completed in about 5 years, subject to the availability of funds appropriated by the U.S. Congress. LIGO will be developed, built, and operated by Caltech and MIT for the scientific community. Occupancy will include a permanent local staff of about 10–20 people, and about 10 visiting scientists. LIGO is an environmentally benign facility and generates no industrial pollutants.

Site Requirements

LIGO will consist of two widely separated gravitational-wave detector facilities in the United States. Each facility includes an L-shaped vacuum system, with arms of 2.5 miles length, made of 4-foot diameter steel pipes with access ports, containing laser interferometric sensor systems. The vacuum pipes provide for straight optical paths along the full 2.5-mile length of each arm. A semi-cylindrical reinforced-concrete vault enclosure protects the vacuum pipes. Located at the vertex of the two arms, and at the midpoint and outer end of each arm, are buildings housing most of the equipment for laser interferometric sensor systems.

Principal requirements of individual sites are as follows:

1. The site must allow the construction of a flat L-shaped foundation slab, 20 feet wide and 2.5 miles long on each arm, which supports the vacuum pipe and its concrete-arch semi-cylindrical enclosure. Foundations for the vertex building, the two midpoint buildings and the two end buildings along each arm will lie in the same plane as the pipe support foundation. A level layout is scientifically best; the elevation difference between the vertex building foundation and either end building foundation may not exceed 40 feet.
2. The site must permit construction of the five major buildings and ancillary structures. The vertex building is 80,000 sq. ft. in area and the midpoint and end buildings are 6500 sq. ft. each. All are 55 feet high above the foundation plane.
3. The layout must avoid earthquake fault lines, floodplains, wetlands, and should minimize road or waterway crossings.
4. The site requires road access for construction and for operation.

5. The site must accommodate a service road adjacent to the 2.5 mile x 2.5 mile system to provide access to entry points along the arms and to the five buildings.
6. The site requires a power hookup with a minimum capacity of 1 MW, delivered to the vertex building.
7. The site requires water supply and waste disposal facilities sufficient for sanitary needs of permanent staff and visitors (20–30 people). (The scientific equipment consumes a negligible amount of matter and generates no liquid or solid wastes.)
8. The site must have geotechnical features that provide good drainage characteristics and soil properties to assure a minimum of foundation settlement (less than 1 inch) after construction. Maximum building foundation load will be 2000 lb. per sq. ft.
9. The LIGO site must be remote from sources of man-made noise, but within convenient commuting distance of housing, schools, and shopping for its resident staff. Convenience of access to an airport for visiting staff will be considered.
10. Costs to be paid by the LIGO Project for all site preparation work required to provide a suitable graded base for foundations and roads (including provisions for drainage and erosion control), and utility connections (power, water, sewer, telephone) may not exceed the budgeted cost of $2,500,000 per site.

Proposal Guidelines

Interested parties are invited to submit a letter summarizing the offer that is being made together with a brief description of how each of the principal site requirements of the previous section will be met. In addition, the submission must include the following supporting material:

1. A map indicating the proposed location of the LIGO site(s).
2. A topographic map (USGS 7.5 minute series, original color copies) with a sketch of the proposed layout(s) for the LIGO arms (2.5 mi x 2.5 mi "L"). (Attach sketches of the elevation profile along each of the 2.5 mi long arms.)
3. Readily available geotechnical data that may be useful in evaluation of site potential.
4. Available data on climate (temperature, wind, precipitation) and environmental risks (earthquakes, landslides, floods, windstorms).
5. A description of the proposed access for utilities and transportation.
6. A description of present ownership and land use of the site.
7. A statement describing the land to be provided, including the proposed price, if any, for sale or lease of the land (any proposed lease must be for a minimum duration of 25 years), and how the proposer will secure transfer of the land to the Government or Caltech.
8. A discussion of potential future urban or commercial development that may encroach upon LIGO requirements.
9. A statement on expected environmental or procedural issues which may affect a timely construction start.
10. A commitment to cooperate in the acquisition of additional geotechnical data needed for construction if the site should be selected for further evaluation.
11. A statement describing any additional support the applicant is prepared to provide.
12. A statement of the period of validity of the submitted offer (180 days minimum).

These submissions will be evaluated for their technical feasibility, scientific suitability, and costs. Subsequently, sites will be paired, based upon scientific requirements including separation and orientation. Additional investigations of these pairs may be conducted. Analyses and recommendations will be submitted to NSF who will make the final selection of sites. Site pairs may be ranked, without any discussions with the proposer, on the basis of initial proposals received. Therefore each initial proposal should contain a proposer's best terms from a cost and technical standpoint. Sites other than those resulting from this solicitation may also be considered. Proposers are advised that NSF may release to the public a list of those who propose and the sites proposed in response to this solicitation. This solicitation does not commit Caltech or the Government to pay costs incurred in the preparation or submission of a proposal or in making necessary studies or obtaining information for its preparation.

Proposal Delivery

The original plus four copies of the proposal, including the letter offer, supporting material, and a list of the names, titles, and telephone numbers of the persons authorized to represent the proposer should be mailed to:

LIGO Project
Mail Code 102–33
Attention: LIGO Site Solicitation
California Institute of Technology
Pasadena, CA 91125

The deadline for receipt of all materials is 4:00 P.M., March 1, 1991. Proposals received after this deadline may not be considered if this would disrupt the ongoing review process.

Inquiries

Any prospective proposer desiring an explanation or interpretation of this Solicitation should request it in writing. Oral explanations or instructions will not be binding on the LIGO Project. Any written information given to a prospective proposer concerning this solicitation will be furnished promptly to all other interested parties if that information is necessary to submitting proposals or if the lack of it would be prejudicial to any other prospective proposers. Therefore, prospective proposers are invited to indicate their desire for notification by writing to the address given below.

Inquiries about this solicitation should be directed to:
LIGO Project
California Institute of Technology
Pasadena, CA 91125
FAX (818) 304–9834 or (818) 795–1547

Site Selection Criteria

The sites chosen should permit the highest level of research productivity and overall effectiveness for the LIGO facility, at a reasonable cost of construction and operation, and

with minimal adverse impact on the environment. Proposals will be evaluated against both technical criteria and cost considerations, using the following criteria:

1. Science Impact

(a) Local Parameters

i. Site topography affecting LIGO facility critical parameters (angle between arms, arm length, slope of arms).

ii. Natural and man-made ground vibration spectra.

(b) Global Parameters

i. The two-site requirement.

ii. Distance between sites.

iii. Relative alignments of U.S. sites.

iv. Geometry (location, and alignment) of site triplets (two U.S. sites and a European site).

2. Construction Cost Impact

(a) Topography (required earth movement)

(b) Soil and subsurface conditions

(c) Hydrology and drainage

(d) Climate

(e) Environmental restrictions

(f) Accessibility (roads, rail, etc.)

(g) Site utilities installation (power, water, sewage, etc.)

(h) Proximity of soil waste and borrow areas

(i) Local labor costs

3. Site Availability and Acquisition Costs

4. Existing Support Infrastructure

(a) Accommodations for resident staff (housing, schools, shopping, etc.)

(b) Accommodations and access for visiting staff (lodging, transportation, etc.)

(c) Local technical support (vendors, maintenance, fabrication, etc.)

5. Operations Cost Impact

(a) Cost of power

(b) Cost of local labor

(c) Heating and cooling requirements

(d) Maintenance requirements

(e) Travel time and costs for visiting staff

6. Risk Factors

(a) Environmental risks (earthquakes, landslides, floods, windstorms, etc.)

(b) Potential future man-made noise from development

7. Security of Facility and Access for Visiting Staff

8. Local Contributions—Financial or Other

5. The site must accommodate a service road adjacent to the 2.5 mile x 2.5 mile system to provide access to entry points along the arms and to the five buildings.
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8. Local Contributions—Financial or Other

Chron

LIGO CONSTRUCTION AT GREEN BANK SITE

Introduction and Summary

The NSF has requested that the LIGO Project explore the feasibility of building a 4-km LIGO installation at the National Radio Astronomy Observatory (NRAO) site near Green Bank, West Virginia. We have visited the site and identified two possible LIGO alignments. Although the Green Bank site is more difficult in terms of topographical complexity than others we have studied, we conclude that it is technically feasible to build a LIGO installation there. A physical description of the two alignments, estimated site-specific costs, and areas of concern are reviewed in the following paragraphs.

Physical Description

The two alignments described here are designated GB–1 and GB–2 (see the attached map, Figure 1, and the two vertical cross-sections, Figures 2 and 3):

GB–1:

	Latitude	Longitude	Tube Elevation
Corner	38° 26′ 12″	79° 50′ 24″	2640 ft
End of Southeast Arm	38° 25′ 03″	79° 48′ 05″	2770 ft
End of Southwest Arm	38° 24′ 33″	79° 52′ 10″	2545 ft
	Direction	**Slope of Tube**	
Southeast Arm	S 58° E	+10 milliradians	
Southwest Arm	S 39° W	−7 milliradians	

Opening Angle: 97°

Special features (See numbers in Figure 1):

1. Deer Creek
2. Highway 28
3. North Fork

Number of Private Land Owners: 14

GB–2:

	Latitude	Longitude	Tube Elevation
Corner	38° 26′ 10″	79° 50′ 18″	2670 ft
End of Northeast Arm	38° 27′ 07″	79° 47′ 51″	2670 ft
End of Southeast Arm	38° 24′ 17″	79° 48′ 58″	2670 ft
	Direction	**Slope of Tube**	
Northeast Arm	N 63° E	≈0 milliradians	
Southeast Arm	S 30° E	≈0 milliradians	

Opening Angle: 87°

Special features (See numbers in Figure 1):

4. Highway 28
5. North Fork
6. Highway 28

Number of Private Land Owners: 7

Estimate of Site-Specific Costs:

	Cost, M$	
	GB-1	GB-2
Earthwork	6.1	16.8
Accomodate special features (streams, etc.)	1.7	1.3
Clear and restore forested areas	0.2	0.3
Provide drainage	0.3	0.3
Concrete enclosure	4.1	4.5
TOTALS	**12.4 M$**	**23.2 M$**

In our previous cost planning we have budgeted approximately 5 M$ for earthwork at an average site, thus, the cost delta for GB-1 is 7.4 M$ and for GB-2 is 18.2 M$. These higher costs for Green Bank reflect not only the topographical complexity but also a major effort to reduce the visual effects on the land (by restoring farmland to a usable state, etc.) to make the plan more acceptable to the private landowners. These costs are best estimates based on our current knowledge of soil conditions; detailed geotechnical data will have to be obtained in order to refine these estimates. "Special Features," i.e. crossings of major public roads, streams, and other necessary accomodations, have been identified as a separate cost item. Because of the popularity of hunting in the area, a concrete enclosure to protect the vacuum tube from rifle bullets has been included as an additional cost for the exposed part of the tube outside the NRAO reservation. The cost of land outside the NRAO property is not included.

Comparison of the Two Alignments, GB-1 and GB-2

Significantly less earthwork is required for Alignment GB-1 than for GB-2. This can be obtained, however, only by tilting the GB-1 arms at a slope of about 10 milliradians. This slope from horizontal is an order of magnitude higher than slopes considered for other sites. Calculations indicate that this tilt would limit low-frequency interferometer performance at the highest expected sensitivities unless new suspension systems, whose feasibility has not yet been demonstrated, could be developed.

GB-2 represents a level alignment that would avoid the low-frequency reduction in performance. Its main disadvantage is increased cost. Advantages of GB-2, in addition to minimum slope, include avoidance of the largest stream (Deer Creek), an alignment within 6 degrees of the optimum for that being considered for the Edwards Air Force site, and the possibility of easier land acquisition (7 private owners compared with 14 for GB-1).

Land Ownership and Acquisition

The feasibility of building a LIGO installation at Green Bank ultimately depends on the cooperation of local land owners. Approximately half of the LIGO installation would be on NRAO property; the other half would be on property now privately owned. While we anticipate no problem with the part located on the NRAO reservation, we would have to buy or lease the remaining land from private owners. We would hope for support from state and local officials in the acquisition of this land. Approximately 100 acres could be affected. The following is a sequence of events required to obtain use of the private land:

1. Determine 2-ft contours for the land in private ownership in order to develop the layout and present the impact of LIGO construction on private property. This would require aerial stereo photography, contour plotting, and identification of land ownership on the plots. Estimated time: 16 to 20 weeks.

2. Evaluate contour data and select exact alignment. Estimated time: 4 to 8 weeks.
3. Engineer the placement of the LIGO on the private land and provide descriptive material for negotiations with the owners. Estimated time: 8 to 12 weeks.
4. Contact and negotiate with owners.

An additional complication is that we probably will not be able to make preliminary geotechnical measurements early in the sequence because this would require permission of the owners before we would be ready to discuss with them the exact alignments and impacts of construction.

Pasadena, January 31, 1989

R. E. Vogt, P.I./P.D.

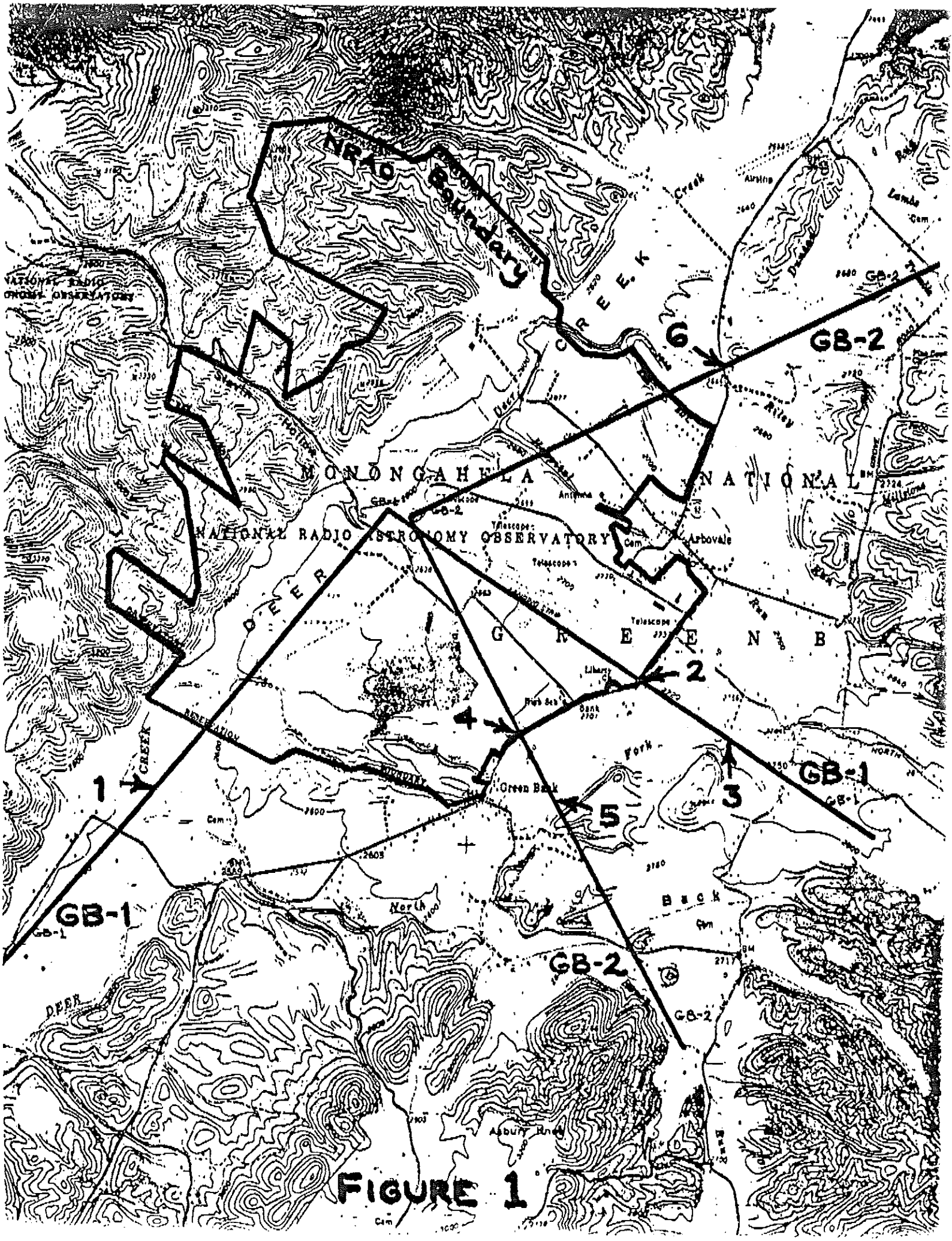
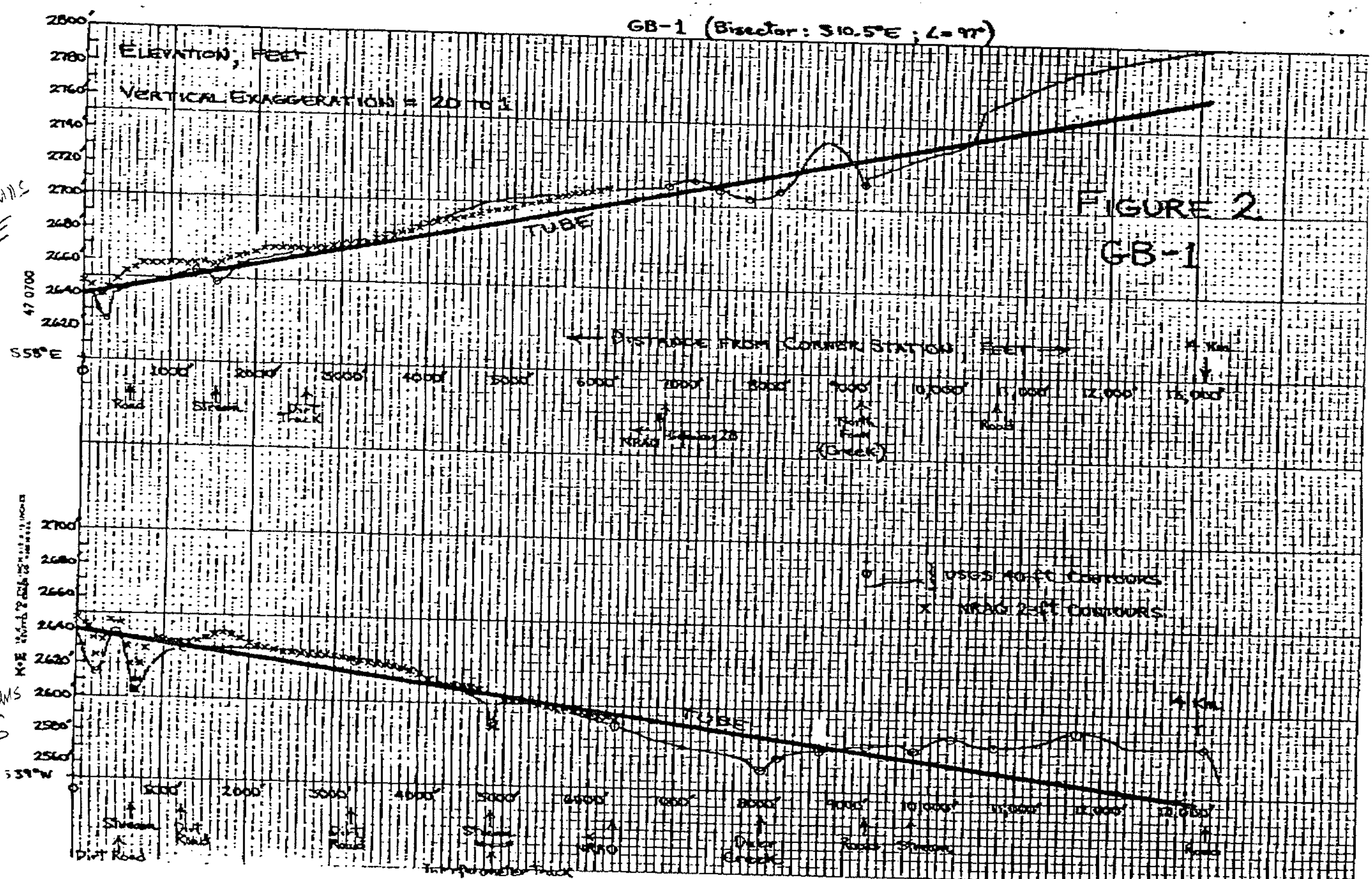
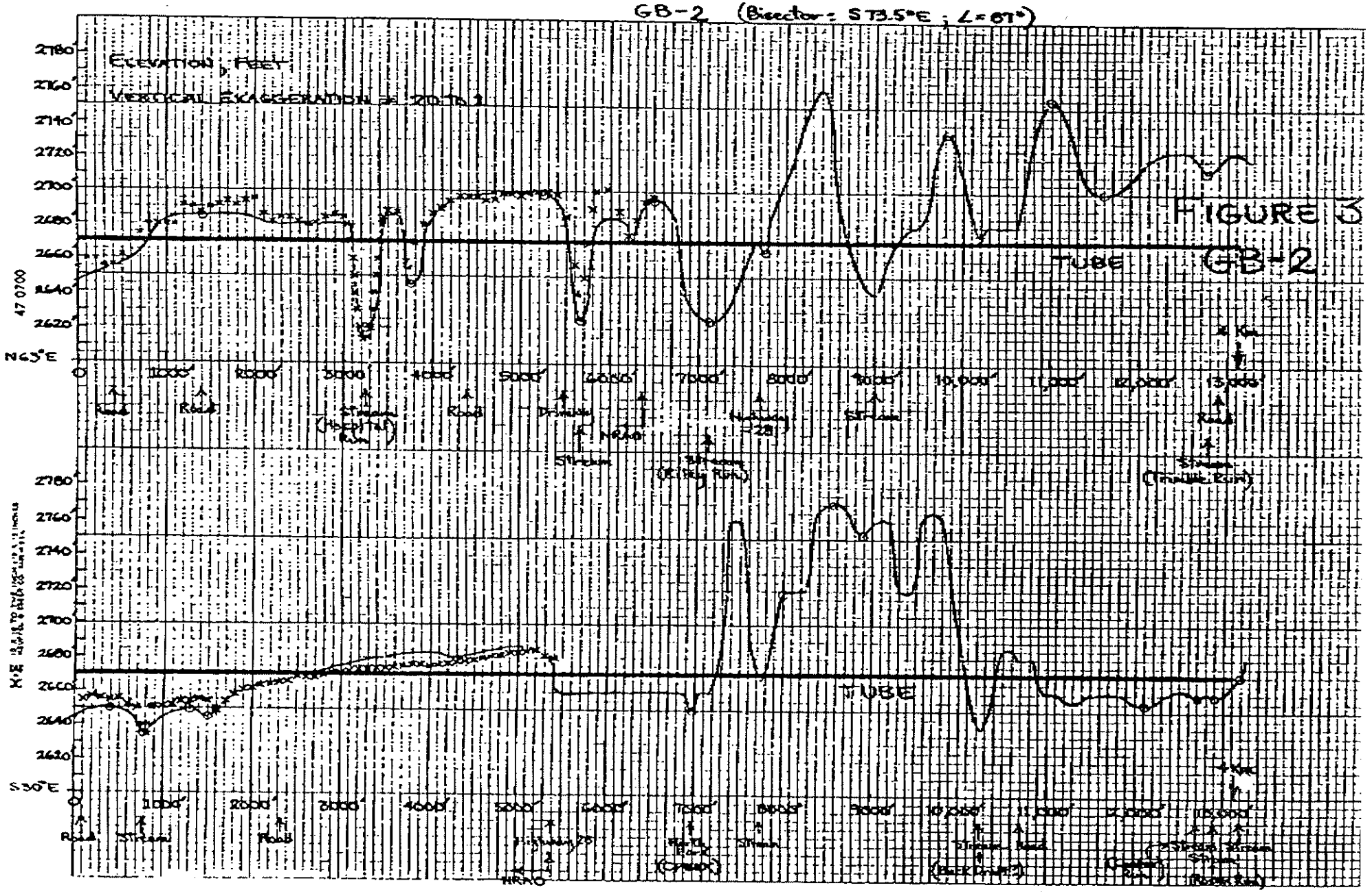

NRAO Boundary
GB-2
GB-1
1
2
3
4
5
6
MONONGAHELA NATIONAL
NATIONAL RADIO ASTRONOMY OBSERVATORY
DEER CREEK
GREENBANK
Green Bank
Arbovale
Deer Creek

FIGURE 1



GB-1 (Bisector: S10.5°E ; ∠=97°)
ELEVATION, FEET
VERTICAL EXAGGERATION = 20 to 1
FIGURE 2
GB-1
TUBE
← DISTANCE FROM CORNER STATION, FEET →
S58°E
E
S
S39°W
USGS 40-ft CONTOURS
NRAO 2-ft CONTOURS
Road
Stream
Dirt Track
Dirt Road
Road
Interferometer Track


GB-2 (Bisector: S73.5°E ; ∠=67°)
ELEVATION, FEET
VERTICAL EXAGGERATION = 20 TO 1
TUBE
TUBE
N63°E
S30°E
FIGURE 3
GB-2

Requirements

1. 20ft × 2.5 miles, flat to within 40 feet
2. five buildings
3. no faults, floodplains, wetlands; minimum road & waterway
4. road access for construction
5. roadway along arms
6. 1 MW power at intersection
7. water & sewage for 20-30 people
8. good drainage; 1 inch settlement w/ 2000 lb/ft² at buildings
9. remote but convenient to housing, school, shopping, airport
10. 2.5M$ max.

- letter summary of offer + description of how each requirement is to be met
- ✓ map + topo
- ✓ geotechnical data
- ✓ climate data
- ✓ utilities
- environmental issues
- ✓ coop pledge
- additional support ?
- land - acquisition - future use

topographic maps	a must	4 originals
local labor costs	✓	
site & travel	✓	originals when possible
state & federal offices	?	
climate info	✓	
geology		

send copy of letter from Triad with preliminary findings & note that this is for area reconnaissance & full report avail.

Xerox of 1956 report