JLC * Sites and Civil Engineering

Revisit and Update

Works

by

Site Study Group & Utility Group

@ISG10

T. Matsuda

KEK/IPNS

(*) Now GLC

Candidate Sites for JLC

Site Study Group

(Sept. 2001 – March 2003)

Two Categories:

(A) 8 Areas of Uniform Bedrock:

(Yellow No.)

(B) 4 Areas of Scientific City or

National Project:

(Blue Characters)

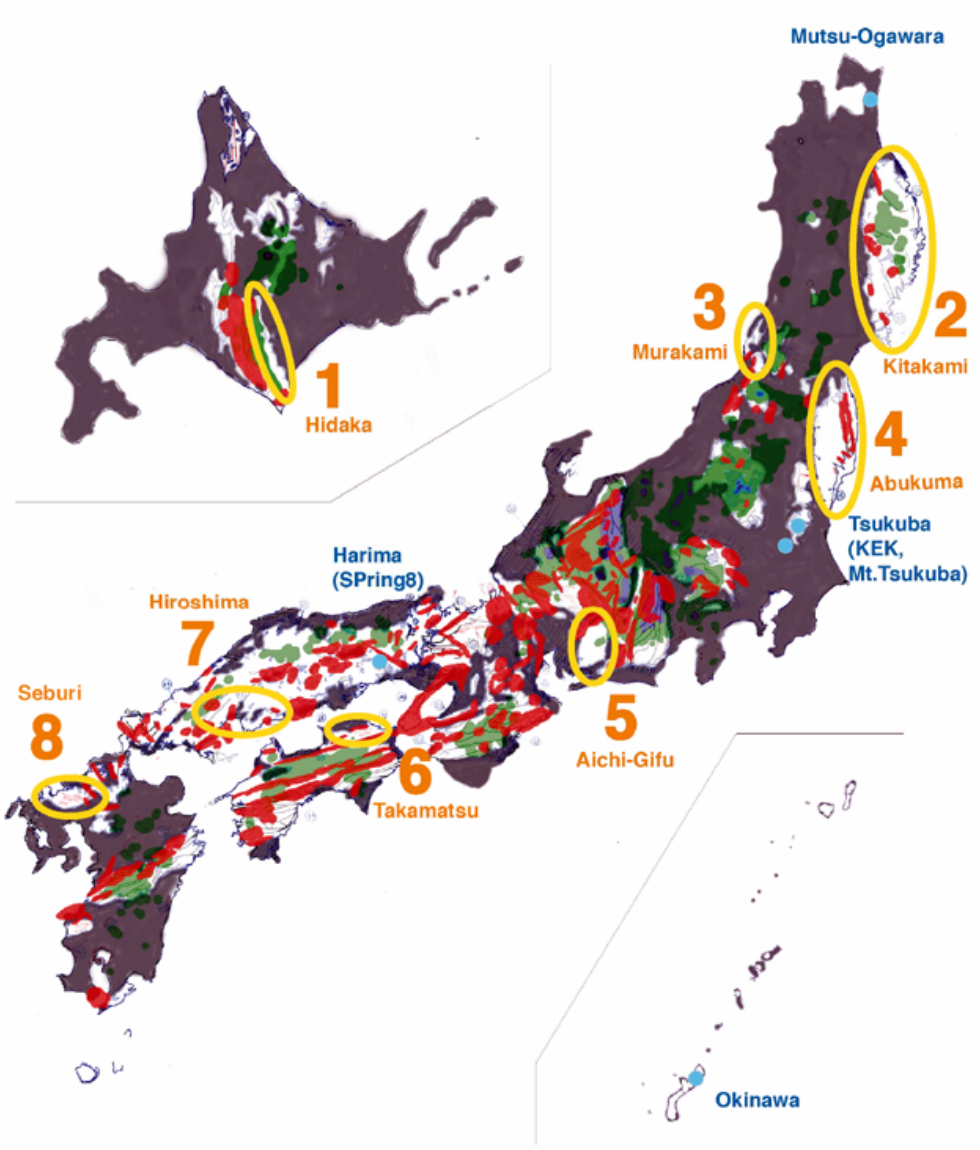


Table 6.3: *Major characteristics and issues of 14 representative routes in 8 (good geology) and 4 (research and development bases) regions.*

n	site	L km	geology	geography	altitude m	depth m	power KV(MW)	T °C	major issues
1	Hidaka	28	granite, hornfels	base of - mountains	270	38-499	**187(526)**	7	power supply capacity,Route274, tunneling in alluvial valley,snow(2m)
2	Kitakami	31	granite	hilly terrain	100	80-600	**275(746)**	10	power flow,quarry,no city
3	Murakami	30	granite	highland	$-5 \sim 70$	36-563	**154(154)**	14	power supply capacity,snow(1m),old mines, mylonite region,quarry ,no city,hot spring
4	Abukuma	36	granite	highland	390	30-300	**275(962)**	11	power flow,golden eagle,quarry
4	Kita-Ibaraki	30	granite	highland	$210 \sim 310$	40-330	**275(1138)**	13	power flow,natural park,quarry
5	Aichi·Gifu (Asuke)	22	granite	highland	$20 \sim 265$	20-200	500(2788)	15	highway,semi-national park,quarry, hot spring
6	Takamatsu	30	granite	base of - mountains	$100 \sim 200$	50-370	500(2788)	15	active faults(3 km)
7	Hiroshima (east)	29	granite	hilly terrain	$250 \sim 300$	40-450	500(1748)	13	clump of rhododendron(1 km)
8	Seburi	38	granite	hilly terrain	$110 \sim 230$	60-520	500(2788)	16	dam construction,quarry,hot spring
	Mutsu-Ogawara	22	andesite agglutinate	base of - mountains	$70 \sim 90$	35-220	154(292)	9	snow(1m),no city
	Tsukuba (KEK)	22	**sedimen-tary layers**	plain	-50	80	500(1788)	14	urban area,stability, road vibration
	Mt.Tsukuba (Bucyouzan)	31	granite metamorphic	hilly terrain	40	30-500	500(1788)	14	JR Mito line,Route50,Joso tunnel, semi-national park,quarry,hot spring
	Harima (Spring8)	30	ophiolite, shale etc.	hilly terrain	40	28-365	500(6712)	14	heterogeneous geology,Chikusa-river, Chizukyu line,hot spring
	Okinawa	24	phyllite, sand	hilly terrain	50	47-326	**(1756*)**	**22**	power supply capacity,rare animals, no city

Here, n, L,altitude,depth, power and T are selected region number, total length, altitude of the tunnel, minimum/maximum depth of the tunnel, nearest power lines and annual average temperature, respectively. Major issues include the most significant items to be further investigated. Non-numbered sites are development and research bases. Bold-faced parts require careful consideration.
* This shows the total power instead of nearest power line, which is available in Okinawa as at May,2003.

Candidate site	Length	Geology	Absence of large river	AC power	Climate and Cultural noise	Environmental impact	Access	Research infrastructure
Hidaka	○	○	◎	△	○	◎	○	○
Kitakami	◎	◎	◎	○	◎	○	○	○
Murakami	◎	○	◎	△	○	○	△	○
Abukuma	◎	◎	◎	○	◎	○	○	○
Kita-Ibaraki	◎	◎	◎	○	◎	○	○	◎
Aichi · Gifu	○	◎	◎	◎	○	○	◎	○
Takamatsu	◎	○	◎	◎	◎	◎	○	○
Hiroshima	◎	◎	◎	◎	◎	○	◎	○
Seburi	◎	◎	◎	◎	○	○	◎	○
Okinawa	○	○	◎	△	○	△	△	○
Harima (SPring-8)	○	○	○	◎	○	○	○	○
KEK	○	*	◎	◎	○	○	◎	◎
Mt.Tsukuba	○	◎	◎	◎	○	○	◎	◎
Mutsu -Ogawara	○	○	◎	◎	○	◎	△	○
Legends: ◎:Excellent ○: Good △: Fair	◎: $> 30km$ without constraints. ○: 20 ∼ 30 km	◎: Hard rock area (granite) * : measuring ground motions.	○: Chikusa-river	△: shortage expected ○: power flow to be investigated.	○: Vicinity of dam, rail road, heavy traffic road, snow (> 1 m),	△: Endangered species.	◎: Vicinity of large city with internat'l schools △: no city with 100,000 residents within 30km.	◎: Close to J-PARC or KEK.

Table 6.4: *Preliminary assessment of candidate sites. Note: For comprehensive evaluation, the weighting factors for the scores in this table require further studies.*

Candidate Site: Two Examples

Area of Uniform Bedrock: Abukuma Site (Route No.1)

Area of Science City: Tsukuba Site (KEK Route)

One Example:

Abukuma Site:

Geology: Mostly Granite.

Diolite-Gabbro.

Geography: Highland

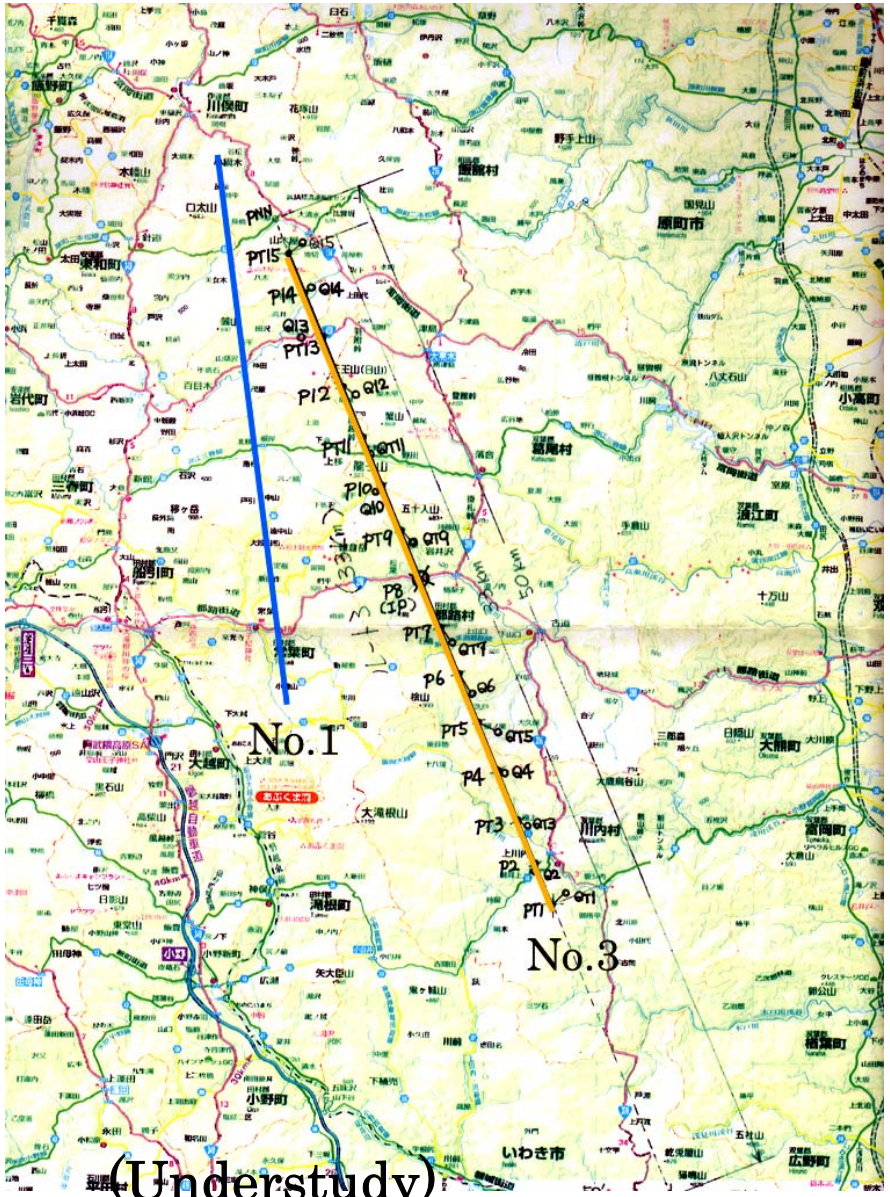
Location; Two Hours Drvies to

North-East from KEK

Three Routes:

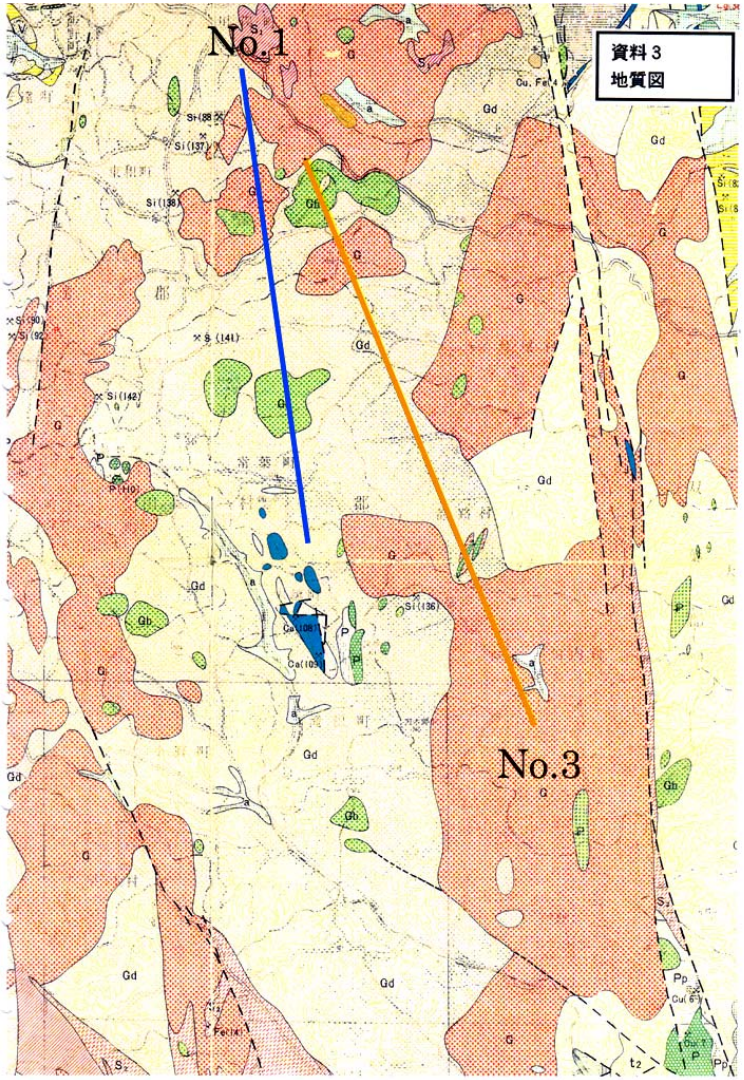
No.1 Route: 27km

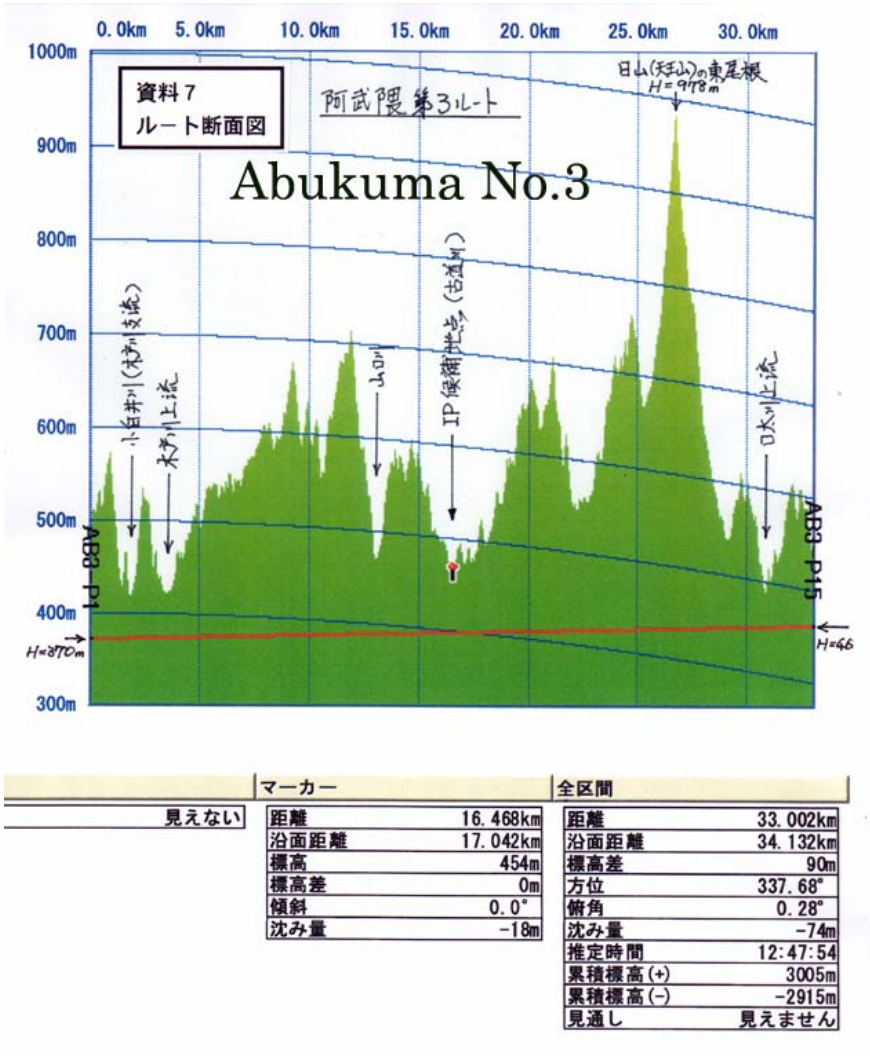
No.3 Route: 33km (Max.50km)



(Understudy)

Abukuma Site: Georogy & Geography





	マーカー		全区間	
見えない	距離	16.468km	距離	33.002km
	沿面距離	17.042km	沿面距離	34.132km
	標高	454m	標高差	90m
	標高差	0m	方位	337.68°
	傾斜	0.0°	俯角	0.28°
	沈み量	-18m	沈み量	-74m
			推定時間	12:47:54
			累積標高(+)	3005m
			累積標高(-)	-2915m
			見通し	見えません

Abukuma Route No.1:　One Example of Tunneling Plan

(For the Standard Accelerator Layout)

Acc. Tunnel (Φ3m):	5 TBM Machines
Klystron Tunnel (Φ4.5m) :	5TBM Machines
	(4.6 - 6.1 km/TBM)
6 Inclined Access Tunnels:	NATM
7 Vertical Utility Shafts (Φ3m):	By Reaming Bits
Experimental Hall (100m deep):	NATM
Vertical Shaft (Φ15m) to Experimental Hall:	
Construction:	About 4 Years

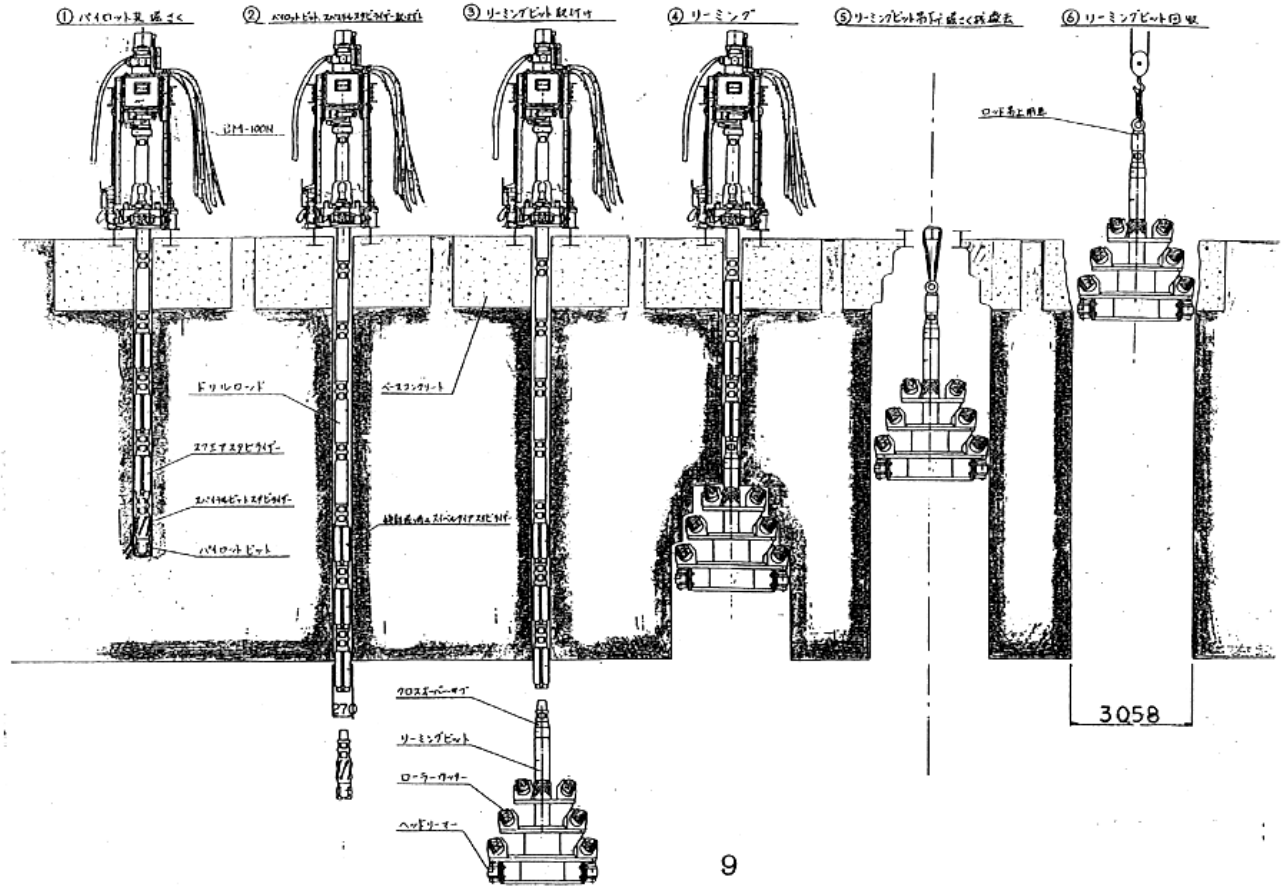
Reaming Bit

立坑（リーミングビット）

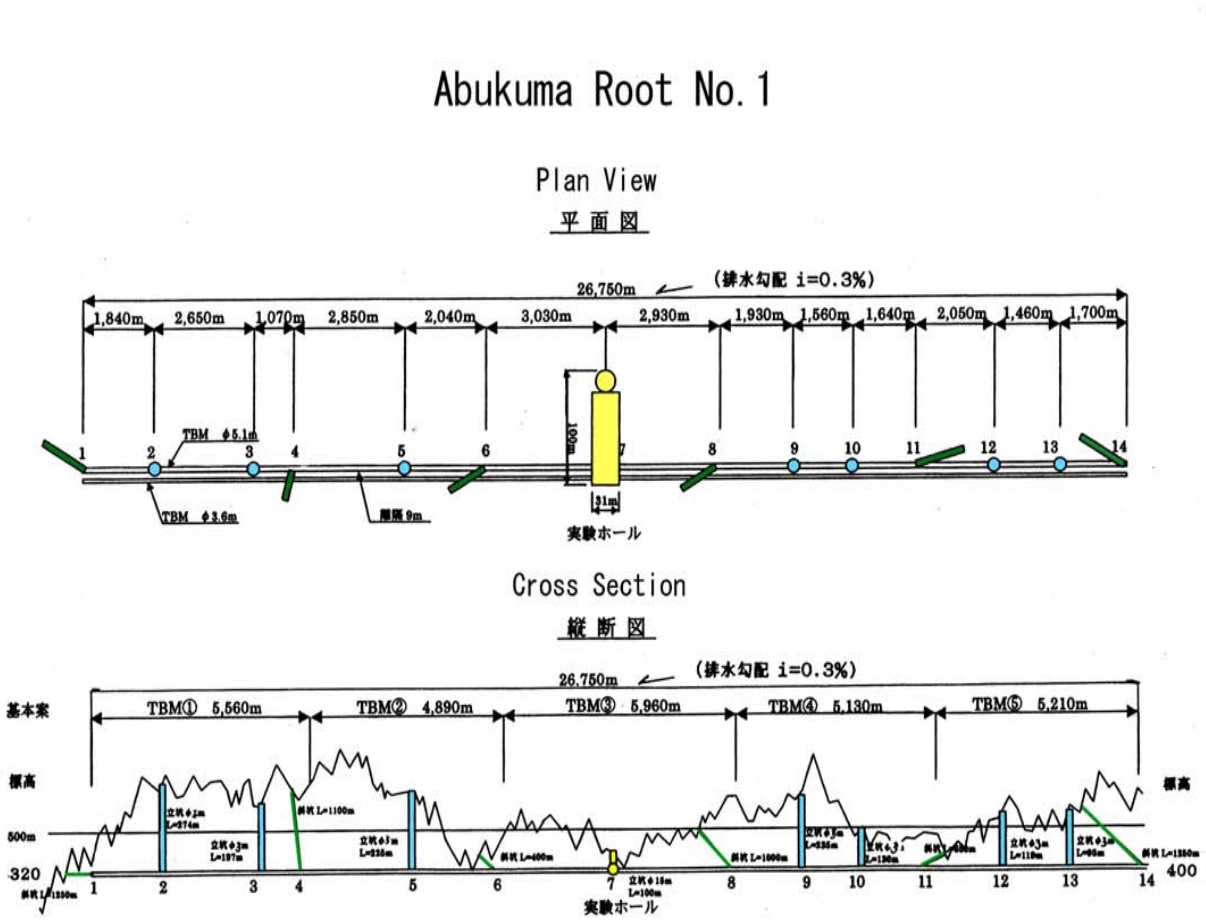
径３ｍの立坑を地上部より鉛直に施工する。立坑は大口径岩盤ボーリング機によりＴＢＭ掘削完了後に施工する。

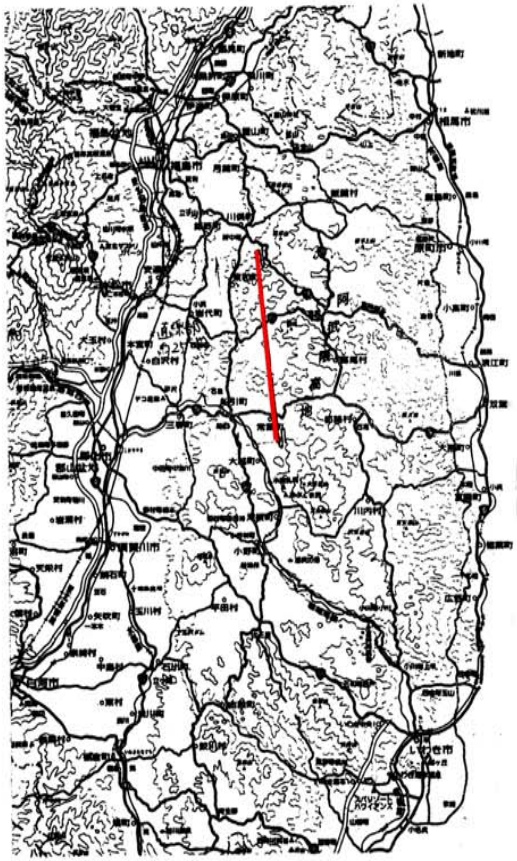
まず、パイロット孔（φ350mm）を、上から下にＴＢＭで施工済みのトンネルまで削孔する。次に拡幅のためのリーミングビットをＴＢＭ坑内で取り付け、下から上に径３ｍで拡幅を行う。掘削ずりはＴＢＭ坑内から搬出する。

掘削完了後、立坑上部より牽引ゴンドラ内で人力により樹脂ファイバー入りモルタル吹付けを５cm掘削面に施工する。



Abukuma Route No.1:　One　Example of Tunneling Plan





Abukuma Route No.1:　Civil Engineering

Construction:　All Feasible.

Options (Vertical Utility Shaft v.s. Horizontal Access etc.)

Cost of Civil Engineering & Construction Time:　27 km Tunnels

$600 - 700M　(Experimental Hall: 23* - 62**M$)　(1$ = 100Yen)

Roughly 4 Years (or Longer for Lower Cost)

May Depend on Details of Geology and Regulations

(Safety, Radiation etc.).

(*) Φ60m, H30m, (*)Φ31, H40m (!)

Another Example: Tsukuba Site

KEK Route: Semimetal Layer (Pleistocene)
80m (> 50m) Underground
Partially Residential Area
Shield Tunnels
Three Plans: 10, 22 (& 33) km

Tsukuba Mountain Route:
Mostly Granite
Mostly Under Mountains
TBM Tunnels
Plan of 31km

KEK Route:

Motivations: (→ISG8)

KEK & Tsukuba Science City

Geology & Geography: (→ISG8)

Semimetal Layer (Pleistocene)

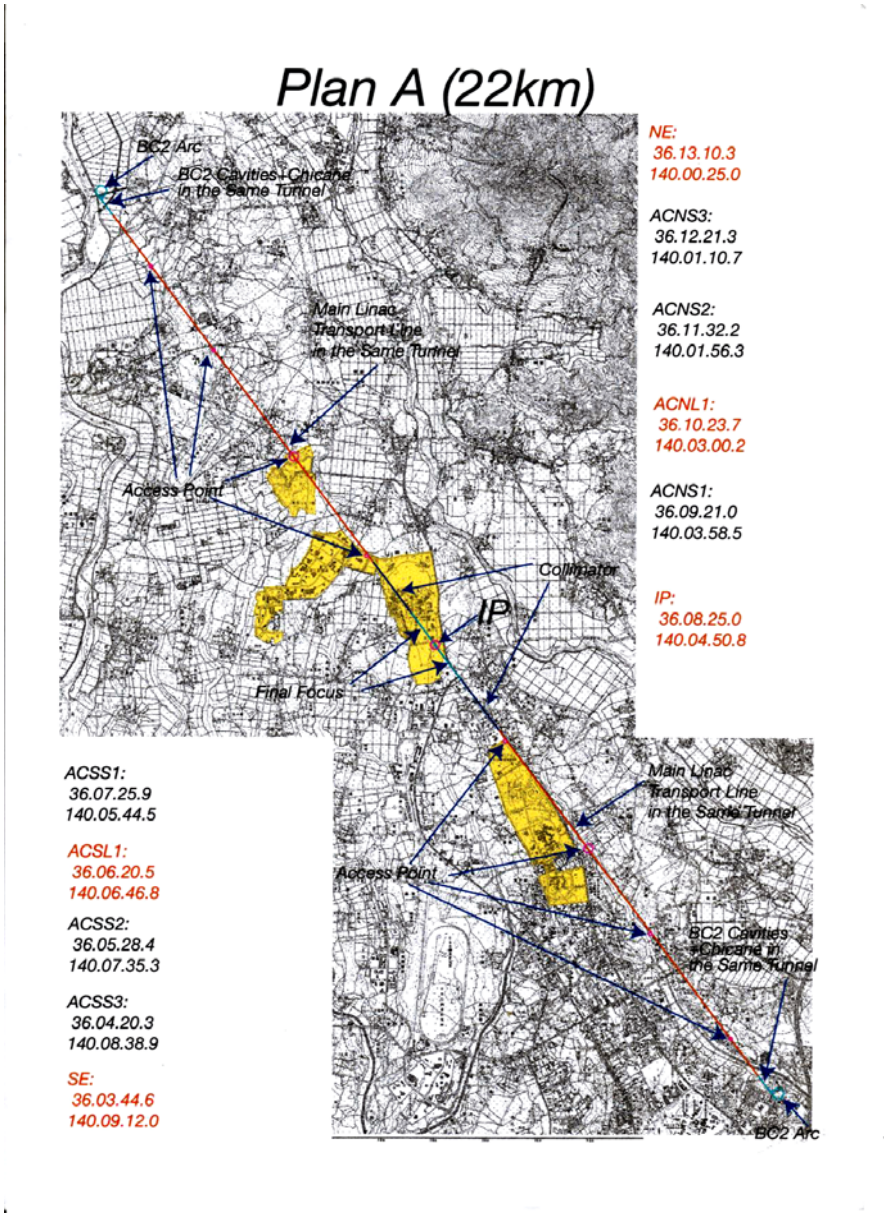
Underground Water (-25mGL)

Tunnel Depth: 80m (>50m)

Three Plans:

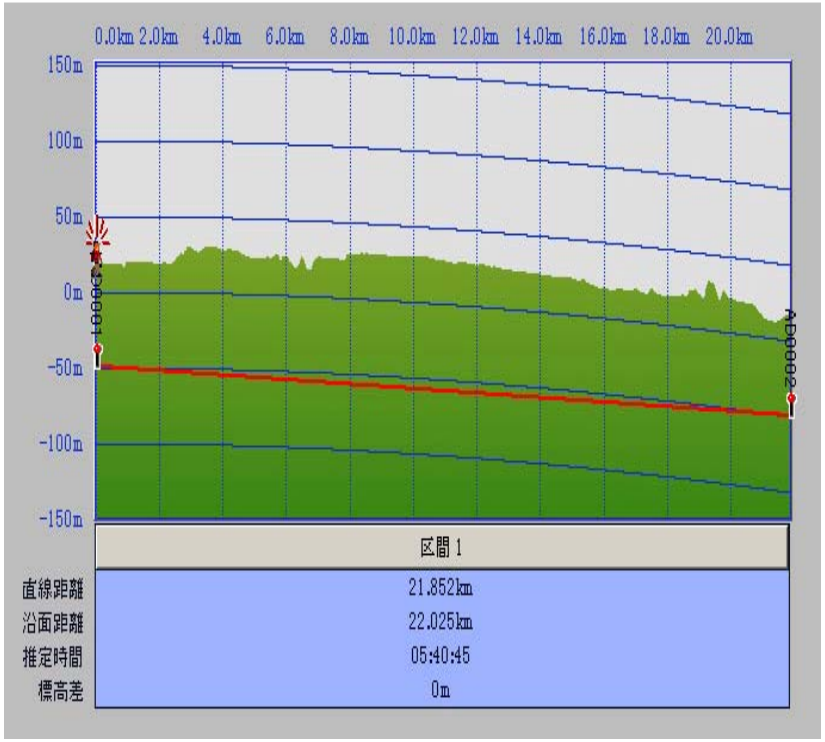
10, 22 & 33 (*) km

(*) preliminary

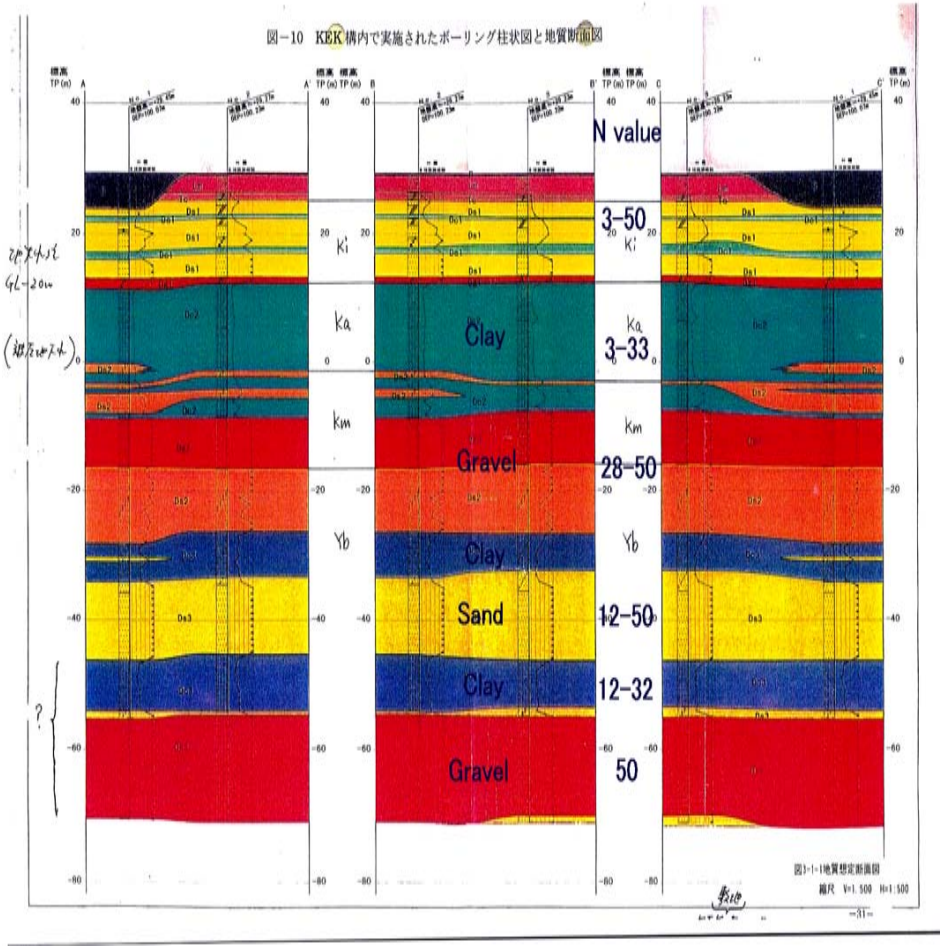


KEK Route: Geology & Geography

JLC @ KEK site
Cross section
(Plan A 22km @ - 60m SL)



Geologic Cross sections
(30m ~ - 70m SL)
(Three borings at KEK)



KEK 22km Route:

IP, Injectors & Beam Dump

Inside KEK.

Dumping Rings

On the Surface.

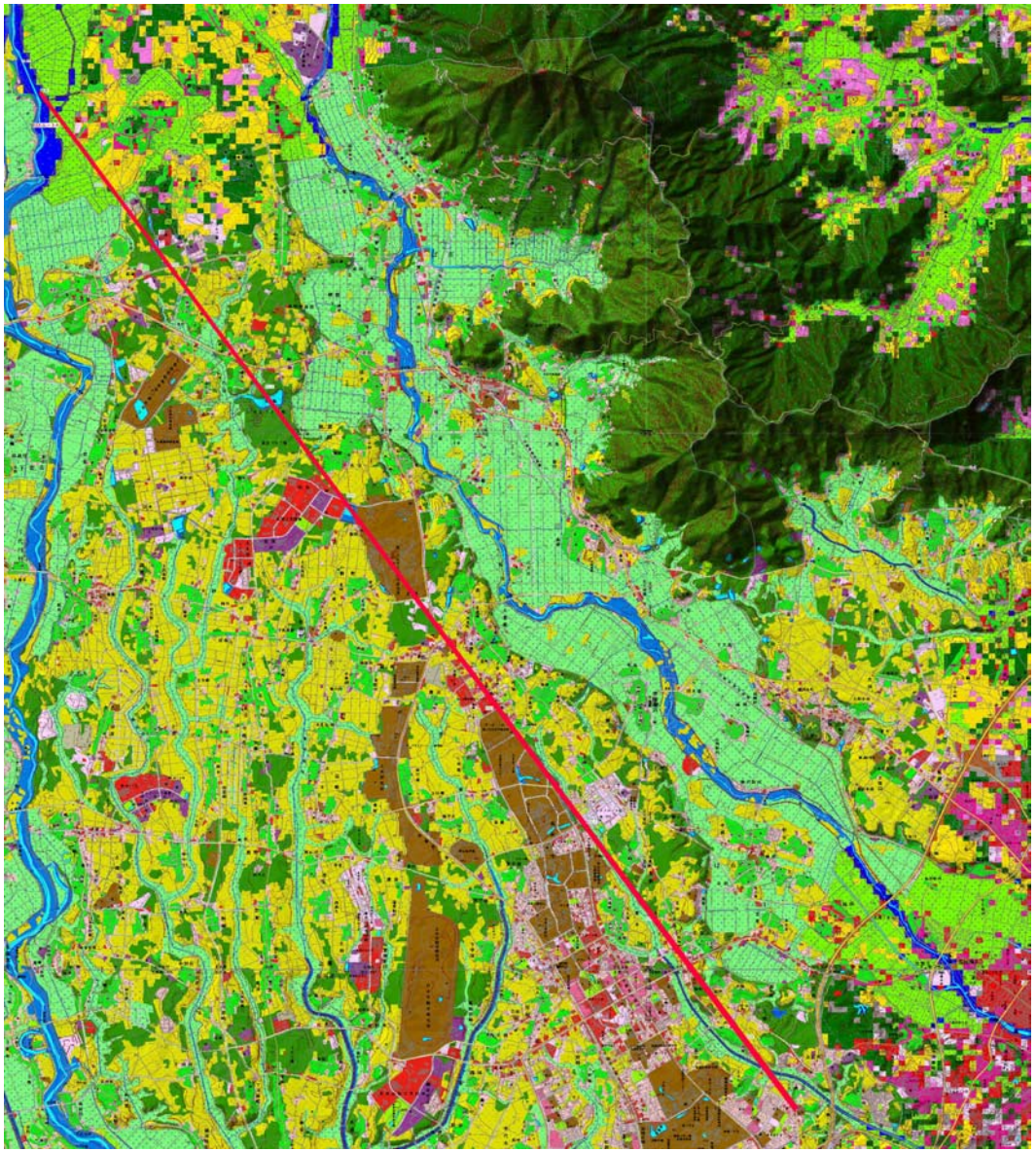
Minimum Facilities

On the Surface outside KEK

Under Tsukuba City

→ Ground Vibration

(Culture Noise)



KEK Route: Accelerator Layout

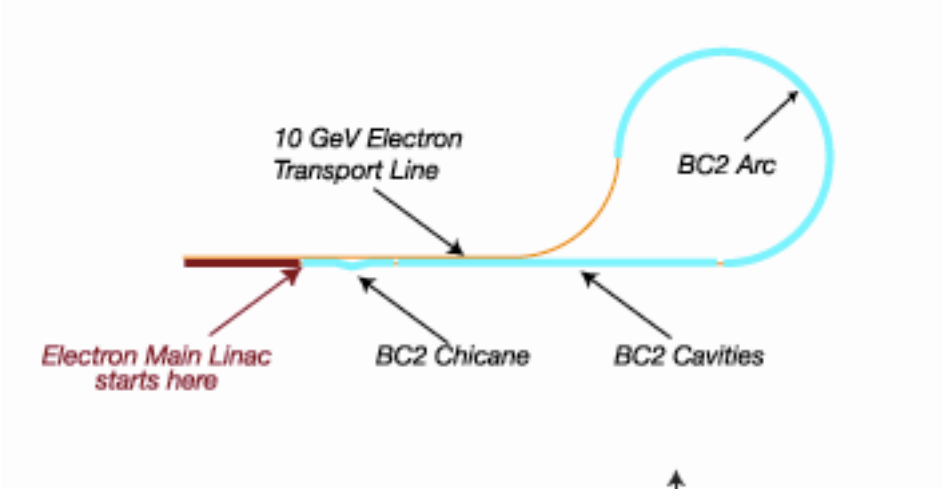
Fig.2

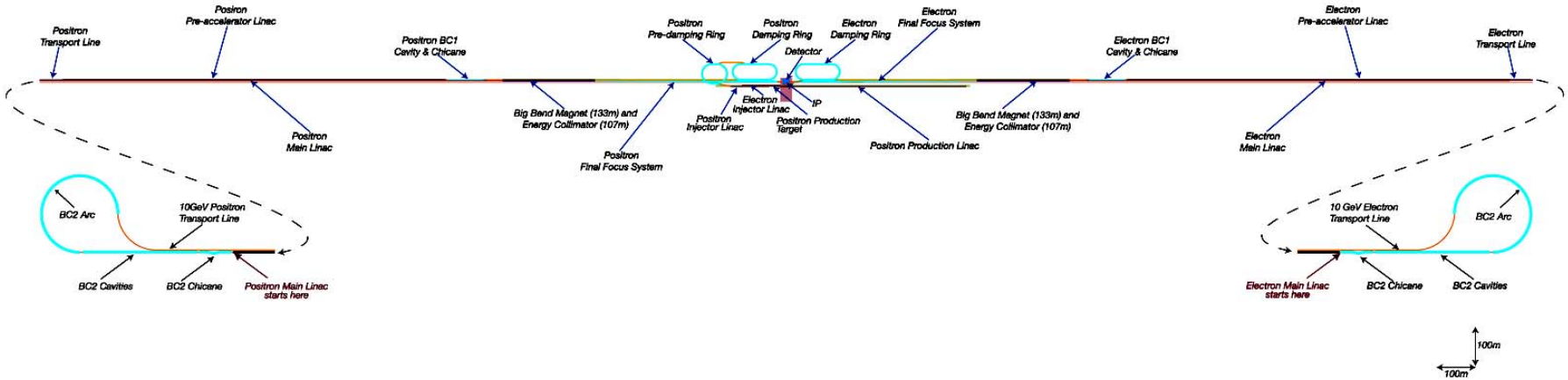
Injector and Pre-accelerator Section

- *Open Cut Tunnels (~10m deep) Klystron Gallery on Top*
- *Slant Tunnels (10% slope)*
- *Accelerator Tunnels and Detector Hall (~80m deep)*
- *Klystron Gallery (~74m deep)*

Collimator Section w/o XY Collimation
107m for Ebm = 200GeV
267m for Ebm = 500GeV

Pre-accelerator Linacs (~1km) have sparsely spaced accelerating structures to share klystron galleries with Main Linacs.





KEK Route: Pre-Accelerator Layout

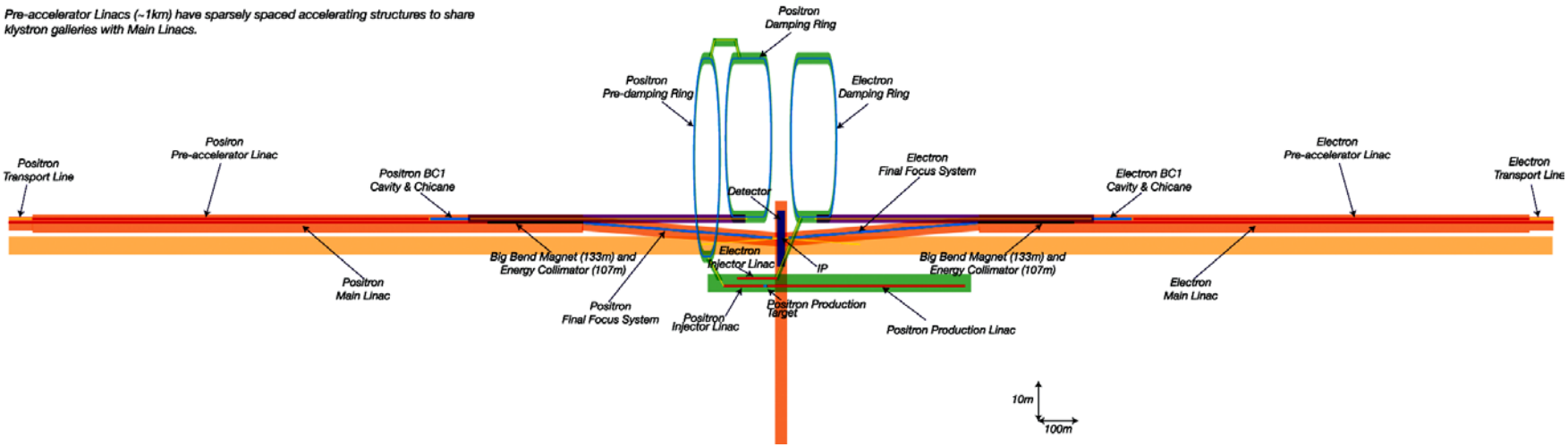
Fig.1-a

Injector and Pre-accelerator Section

- *Open Cut Tunnels (~10m deep) Klystron Gallery on Top*
- *Slant Tunnels (10% slope)*
- *Accelerator Tunnels and Detector Hall (~80m deep)*
- *Klystron Gallery (~74m deep)*

Collimator Section w/o XY Collimation
107m for E_{bm} = 200GeV
267m for E_{bm} = 500GeV

Pre-accelerator Linacs (~1km) have sparsely spaced accelerating structures to share klystron galleries with Main Linacs.

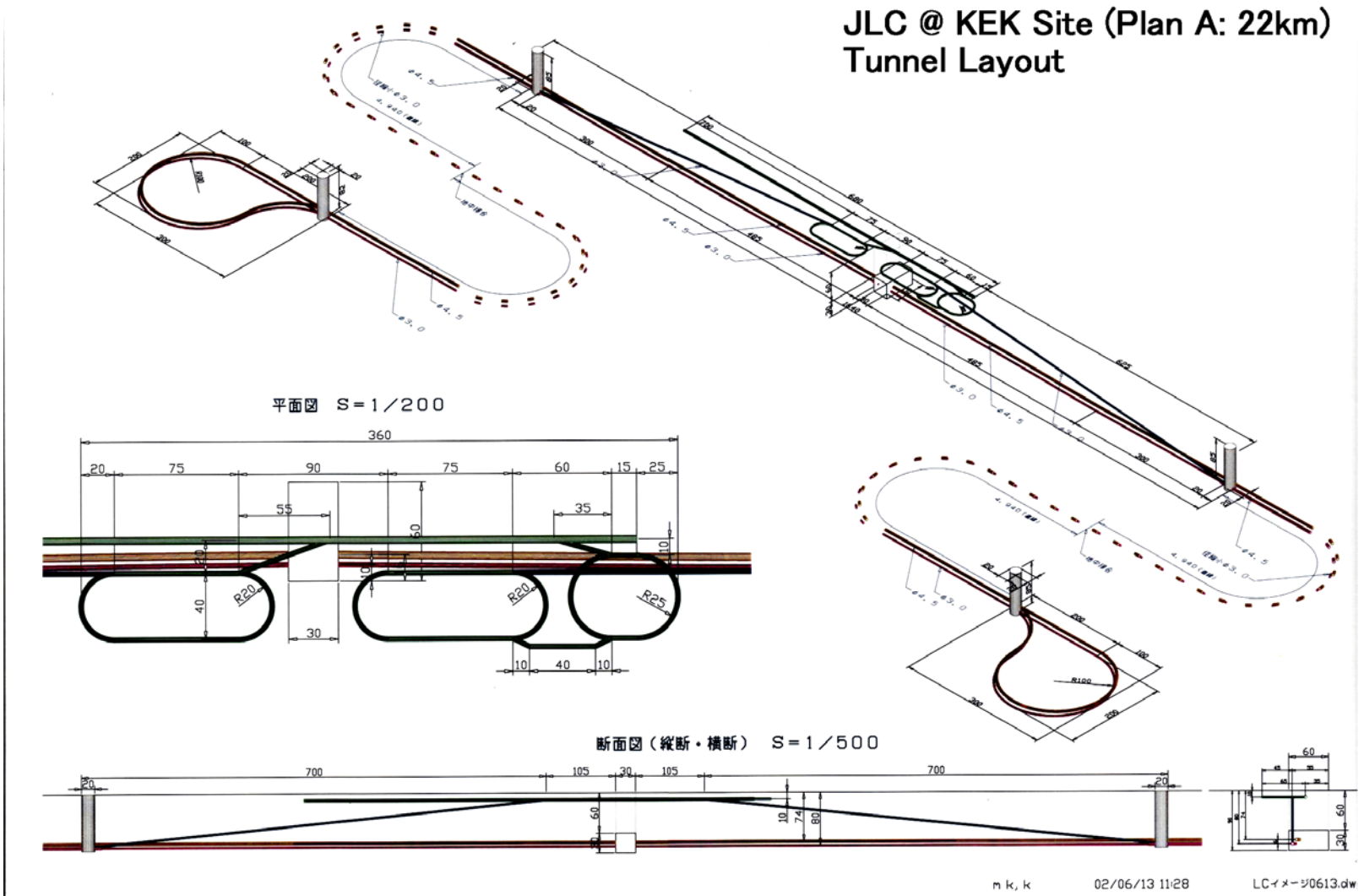


KEK Site: Plan A (22 km)

Tunnel Layout

- **Injector system up to the damping rings is on the surface (-10 m).**
- **Inclined (10 %) tunnels to transport 1.98 GeV electron and positron to the main linac tunnel (~ -80 m).**
- **Main linac tunnel (3 m ϕ) with an arc at each end at ~ -80m.**
- **The cross section of the main linac tunnel is "locally expanded" (3 mϕ $\rightarrow$ 4.5m ϕ) to accommodate the first bunch compressors and the pre-linacs are installed in the main linac tunnel.**
- **The main linac tunnel (of the standard cross section of 3 m ϕ) also accommodates the transport lines, the second bunch compressors.**
- **The klystron tunnel (4.5 m ϕ) and the main linac tunnel, which is separated by 5 m, are located diagonally so that one shaft can serve for the two tunnels in the drilling and the operation.**
- **In some case, the underground conjunction of two tunnels is made without shaft improving the stiffness of the soil by the freezing technique or the injection (hardening agent) method.**

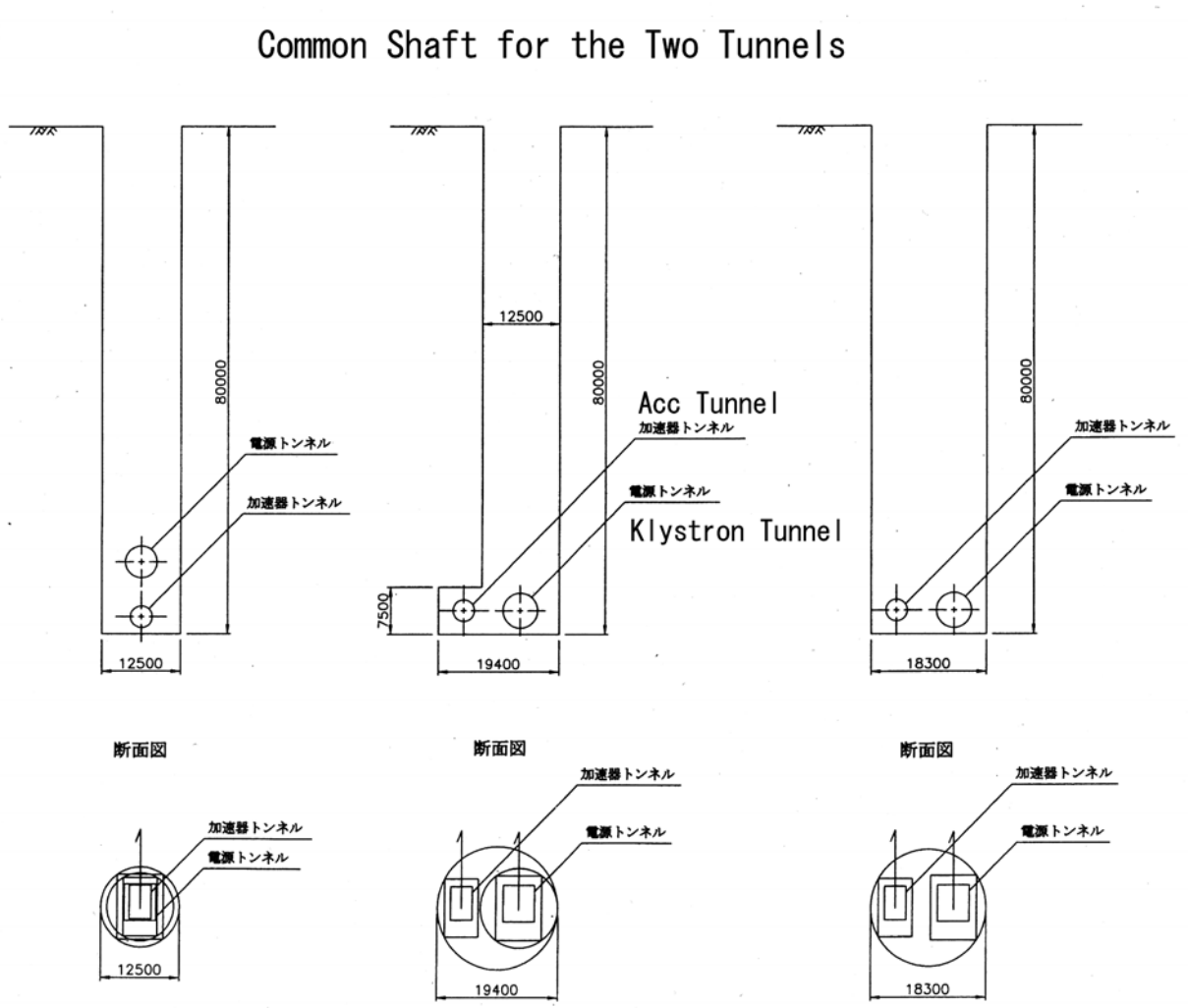
KEK Route: Tunnel Layout (3D)



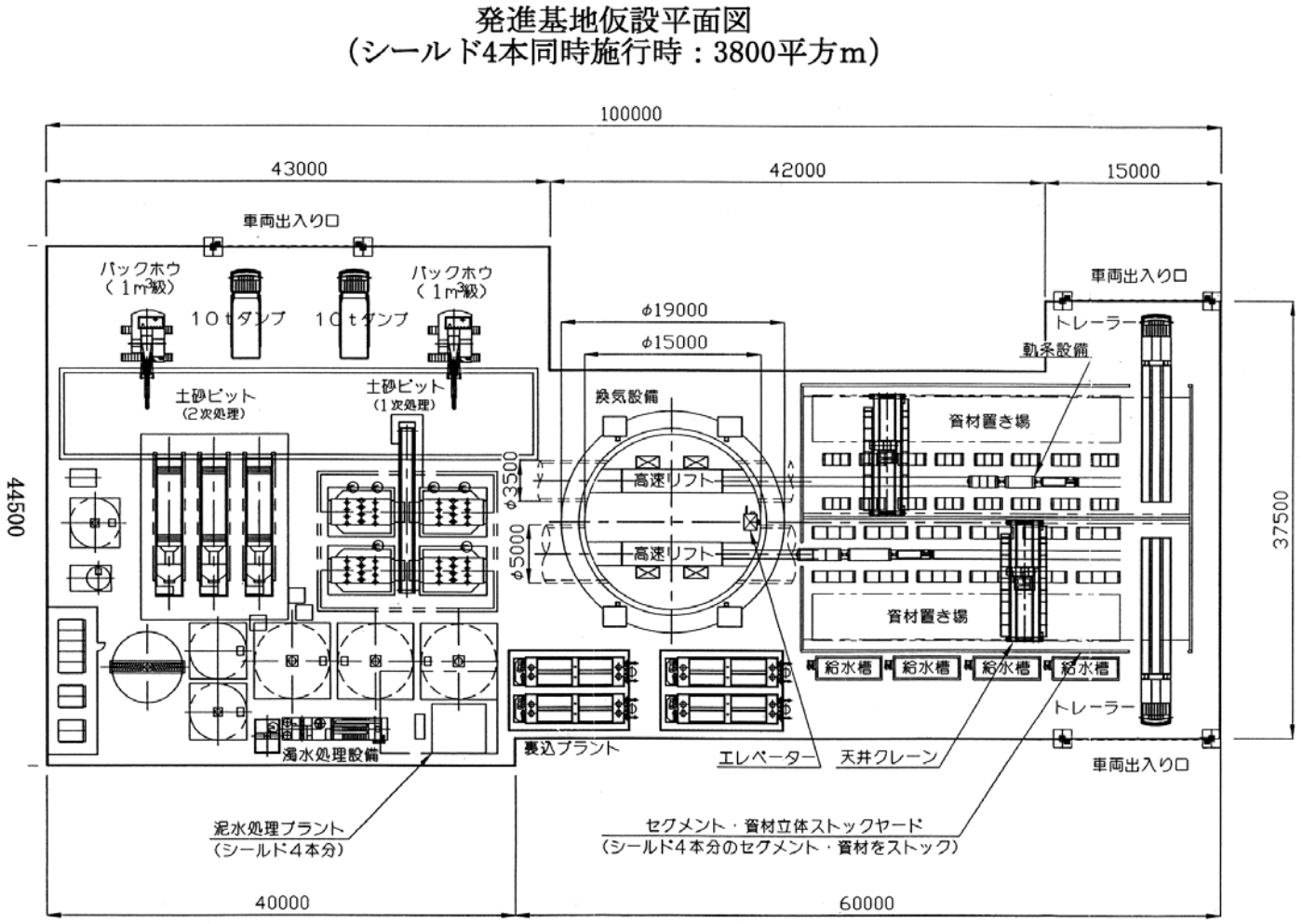
KEK Route: Tunnel Layout (Shaft)

Each Shaft Serves

2-4 Shield Machines for Acc. Tunnel & Klystron Tunnel.



KEK Route:　Base to Serve 4 Shield Machines



KEK 22km Route: An Example of Tunneling Plan

(Among Many Variations)

Acc. Tunnel (Φ3m)

& Inclined Beam Transfer Tunnels:

6 Shield Machines.

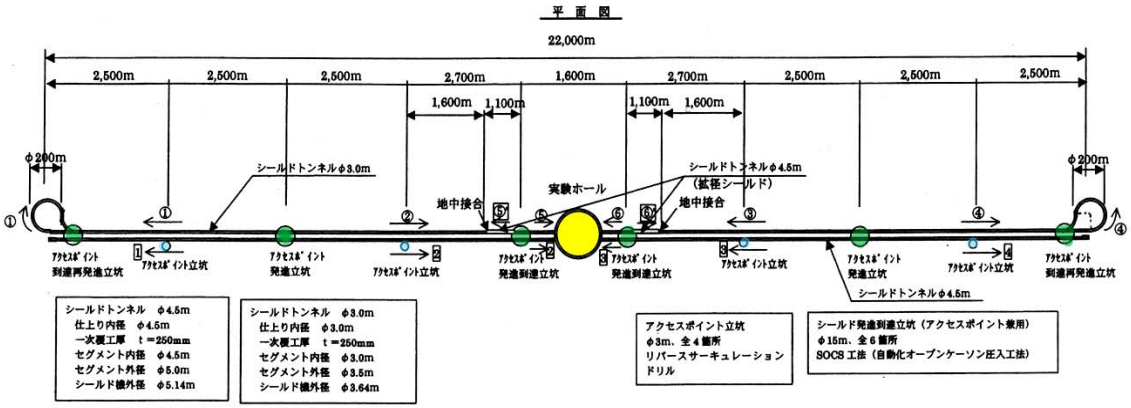
Klystron Tunnel (Φ4.5m) : 6 Shield Machines with Two Modified (Φ3m →Φ4.5m)

6 Large Shafts (Φ15m) : Automatic Open-caisson.

Tunnel Merge without Shaft (Two Locations):

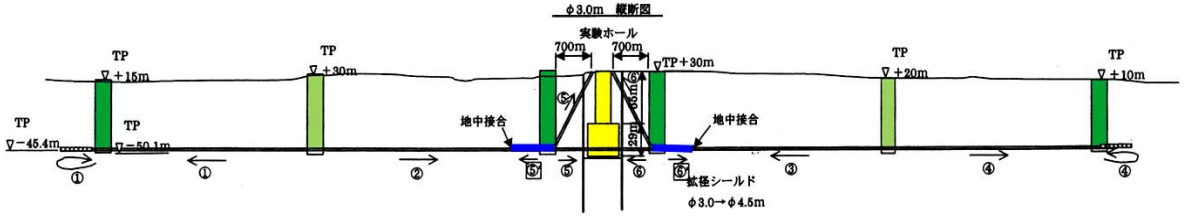
4 Utility Shaft (Φ3m): Reverse Circulation Drill

KEK 22km Route: An Example of Tunneling Plan

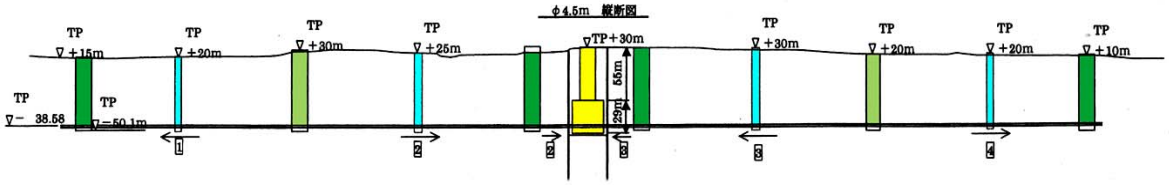


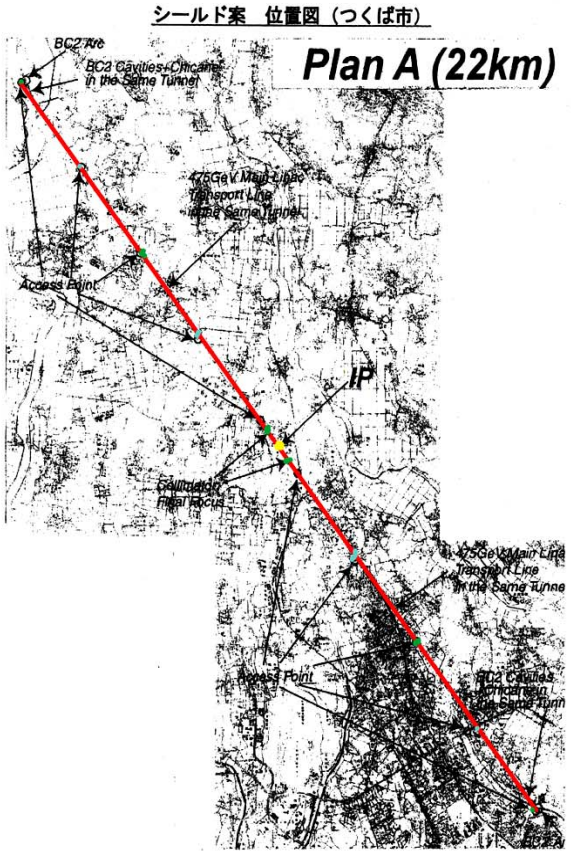
Acc. Tunnel ϕ3m

(ϕ4.5m around IP to accomodate BC1 & Pre-liniac)



Klystron Tunnel ϕ4.5m





KEK 22km Route: An Example of Tunneling Plan

(Many Other Options)

(*) Acc. Tunnel: Partially Φ4.5m

Klystron Tunnel :			Acc. Tunnel : Φ3.0m(*)		
Shield Machine	Excavation (kim)		Shield Machine	Excavation (km)	
No. K1	5.0		No. A1	5.63	R=100m
No. K2	5.2+08		No. A2	4.1	Merge with K5
No. K3	5.2+0.8		No. A3	4.1	Marge with K6
No. K4	5.0		No. A4	5.63	R=100m
No. K5	1.1	Recycle A5 Marge with A2	No. A5	0.7+0.8	
No. K6	1.1	Recycle A6 Marge with A3	No. A6	0.7+0.8	0.7km:Inclined Tunnel
All	24.2		All	22.46	

KEK Route: Major Issues

1. Ground Vibration (Culture Noise): Measured at GL-80m (->Tauchi)
2. Long Term Stability (Drift) of Tunnels in Pleistocene Semimetal Layer.
3. Cost of Large Underground Experimental Hall: New Method?
4. Cost of Shield Tunnel in Japan:

   Still Higher Than Other Countries.

   1.5 - 2.0 x TBM.
5. "Accelerator" Partially Under Residential Areas of Tsukuba City:
6. ,,,,,,,,,,,,
7. Future of KEK :

KEK Route: Experimental Hall

1. City NATM: Cheep but Feasibility with High Underground Water?

2. Diaphragm Wall Method: Feasible but Expensive.

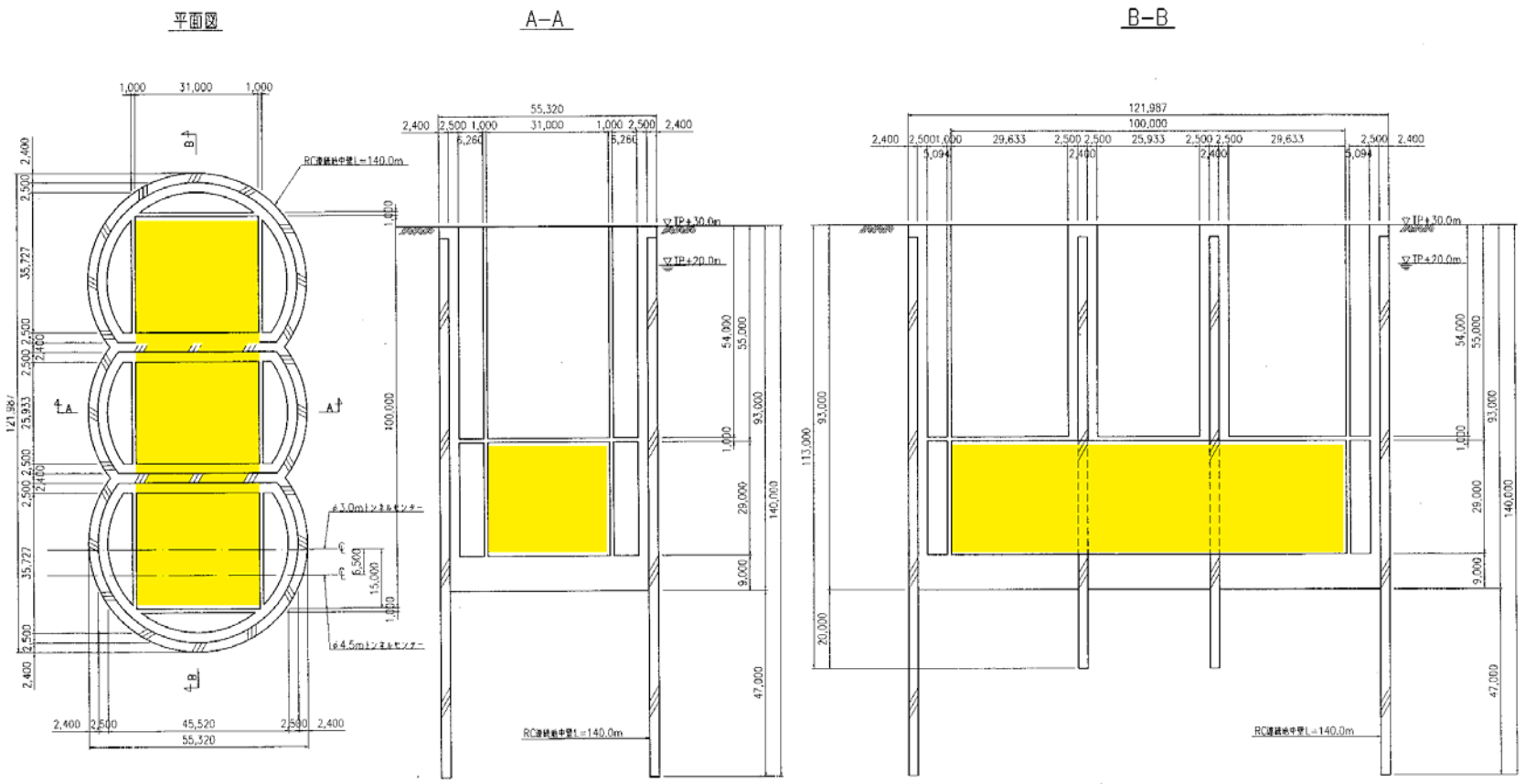
3. Whale (Dinosaur) Bone Roof Method:

   Very Interesting

   But No Real Experience Yet.

KEK Route: Experimental Hall (Diaphragm Wall)

3 x Φ50m Experimental Hall (31mΦx100mL) by Three Diaphram Walls

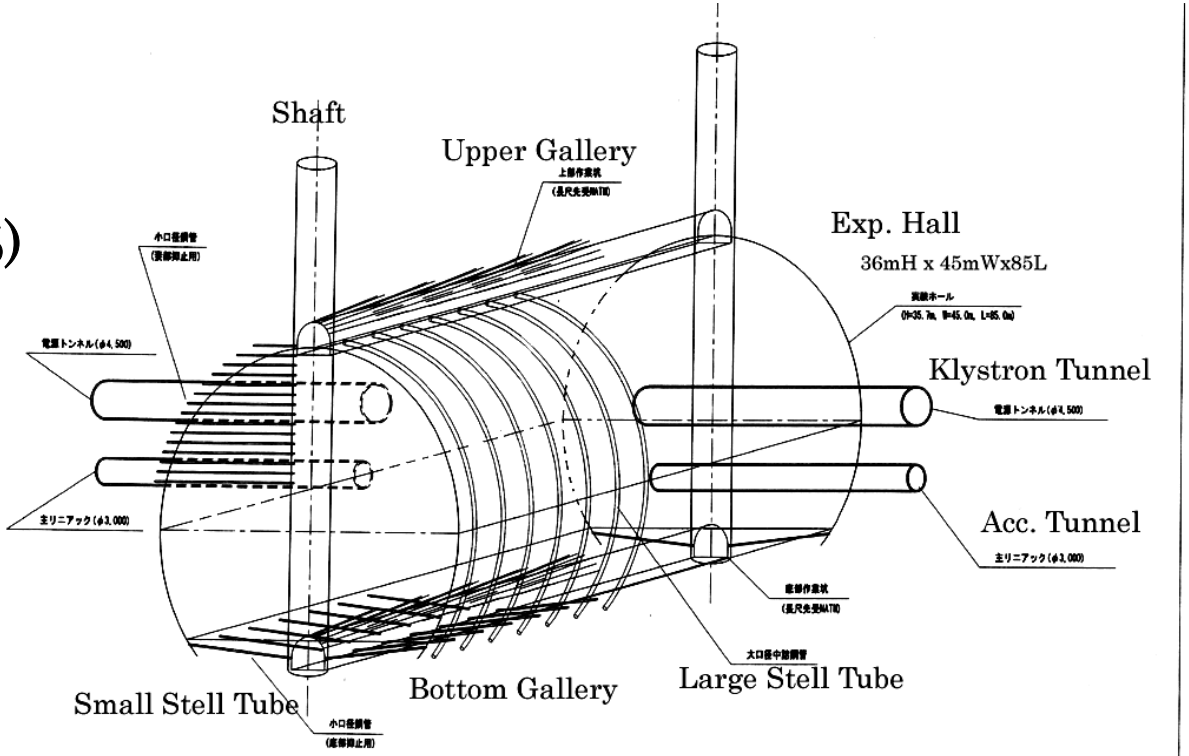


KEK Route: Experimental Hall (Dinosaur Bone)

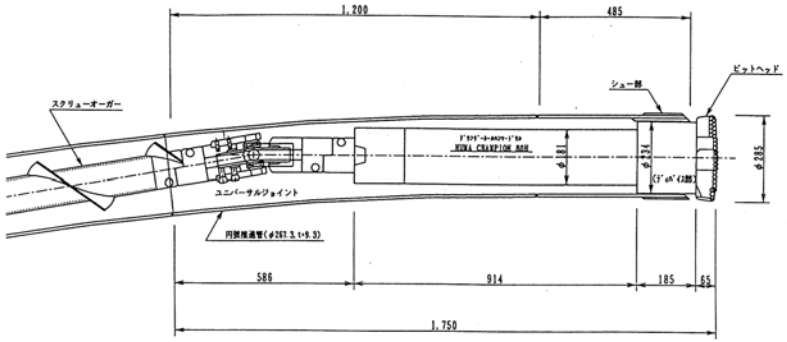
Technology in R&D Stage:

"Wakunami" Tunnel ('01-'05)

(R=5.0 and 6.3 m)

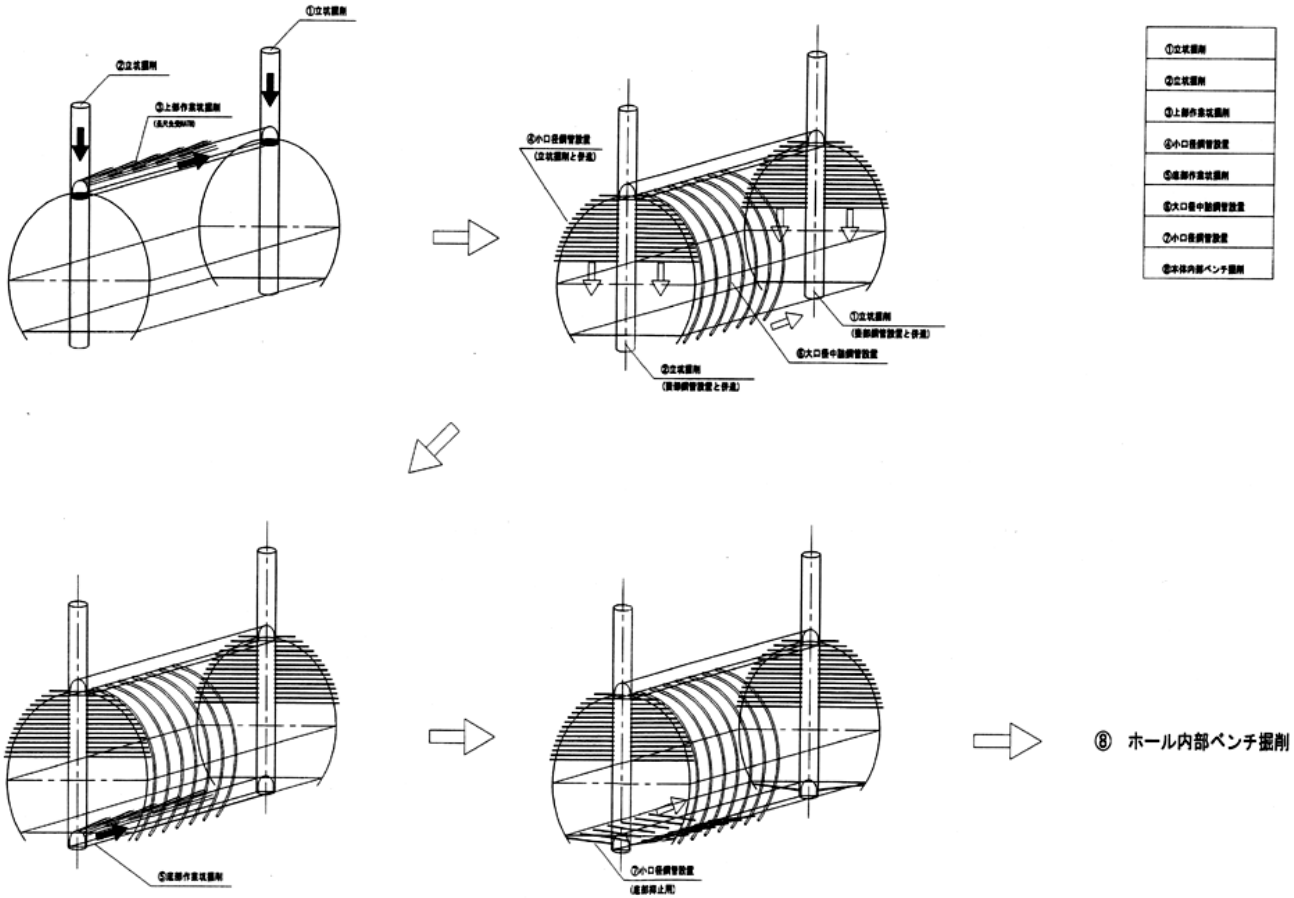


※ 粘性土・土丹で、地下水と共に流出することのない地山を対象とする



KEK Route: Experimental Hall (Dinosaur Bone)

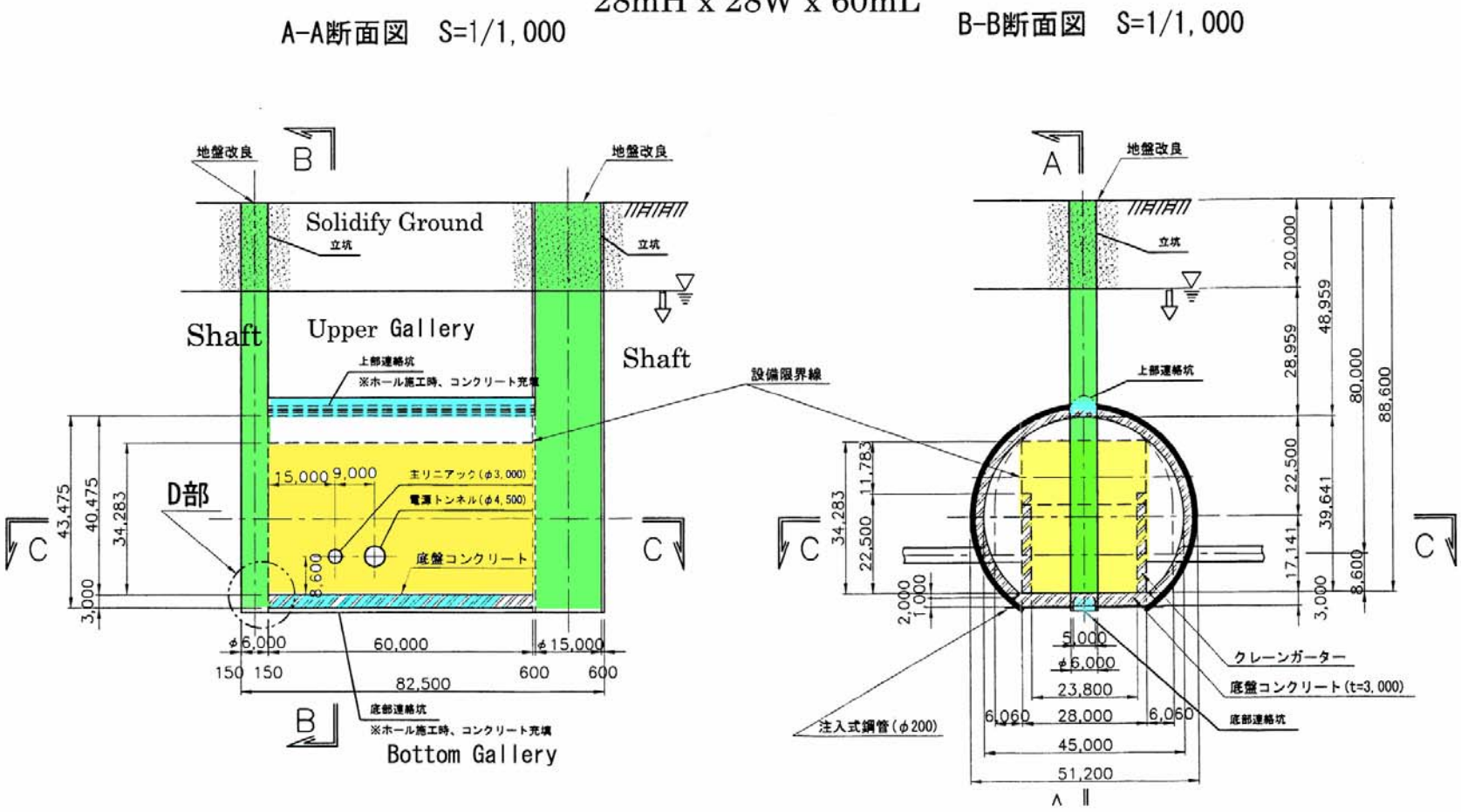
施 工 順 序



KEK Route: Experimental Hall (Dinosaur Bone)

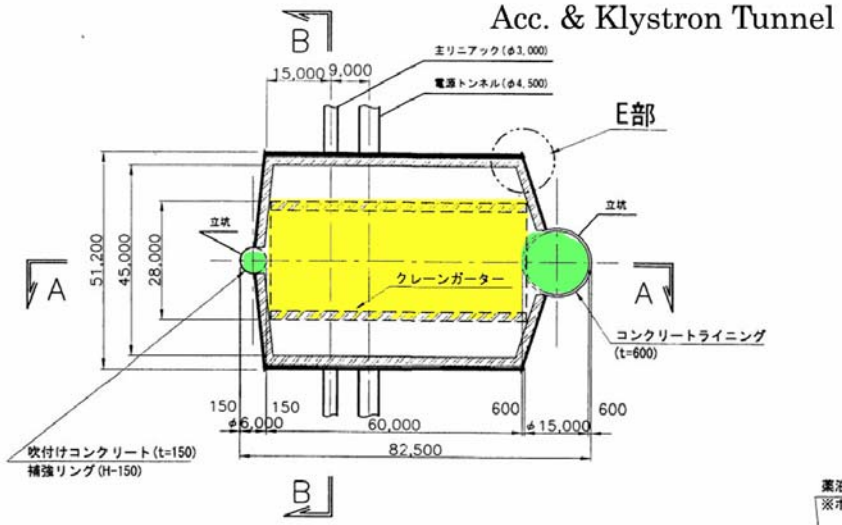
(30m x 30m x 60m)

28mH x 28W x 60mL



KEK Route: Experimental Hall (Dinosaur Bone)

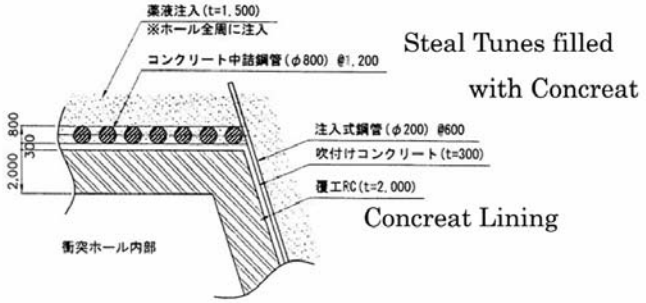
C-C断面図　S=1/1,000



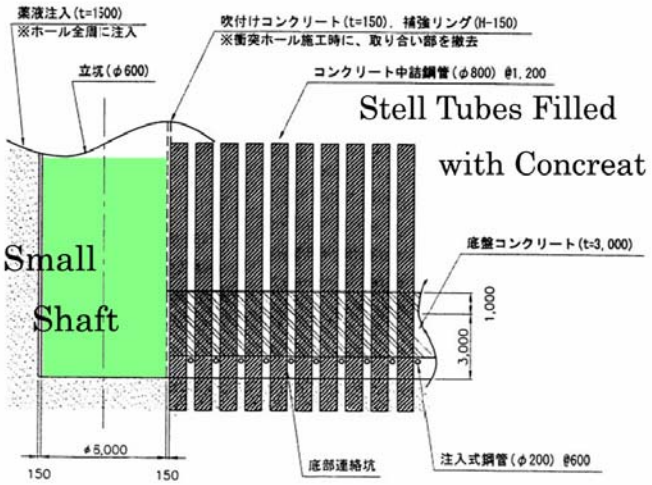
Water Proof Structure

JLCつくばサイト　実験ホール
≪ザウルスボーン工法案≫
---　止水構造の場合　---

E部詳細図　S=1/200



D部詳細図　S=1/200



KEK Route: Civil Engineering

Construction:

Tunnels and Shafts: Feasible. Many Options.
Various Advanced Shield Technologies.

Experimental Hall: Major Technical Issue (Dinosaurs Bone?)
Expensive.

Cost of Civil Engineering and Construction Time: 22 km

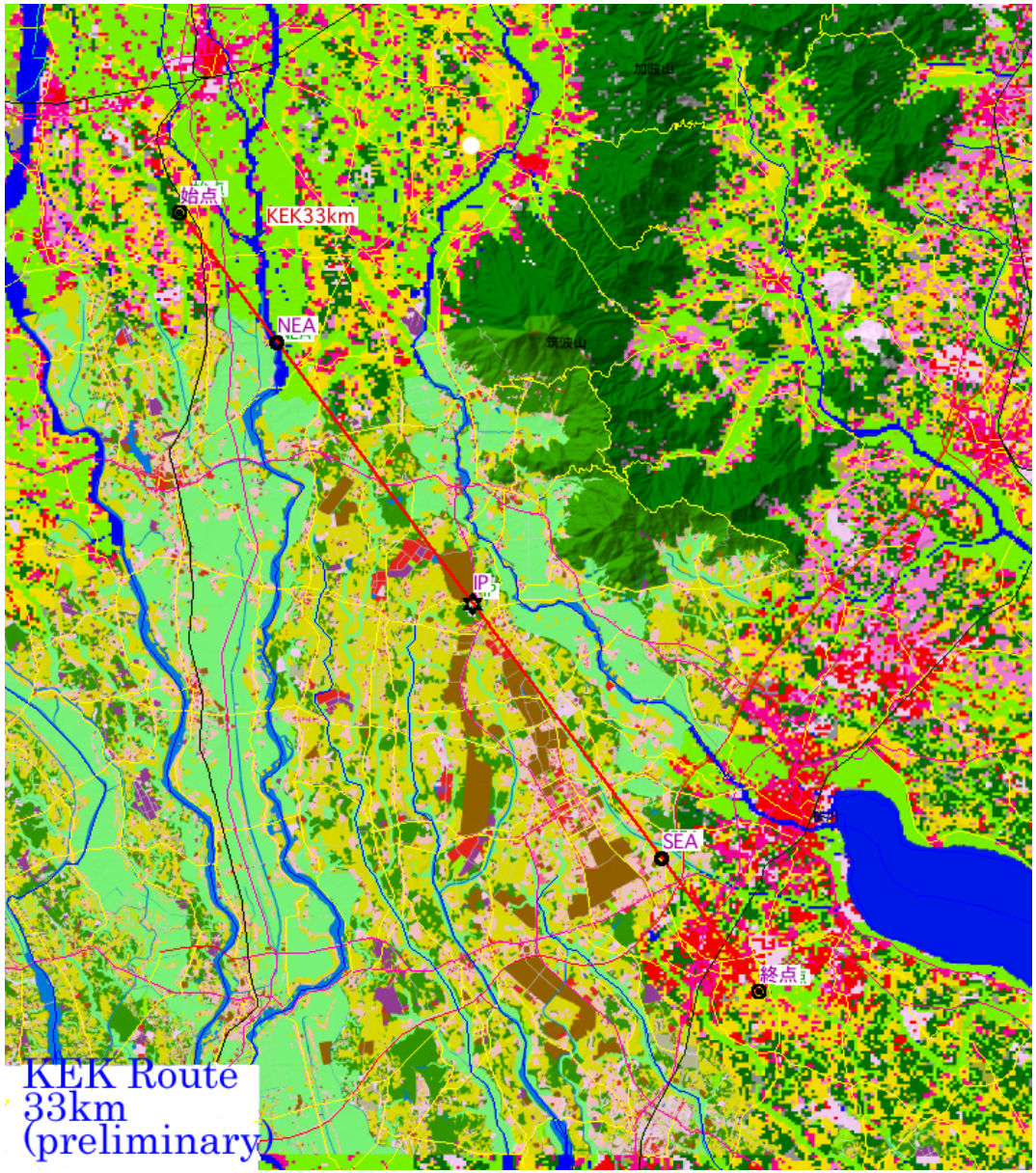
940 - 990M$ (Experimental Hall*: 150 – 170M$)
About 5 Years.
Not Much Depend on Details of Georogy.

(*)Diaphragm Wall, Φ50m.

KEK Route 33km:

Change Direction to
More North-South?

At South End:
Joban Highway
(Better than
Higashi Ohdori?)
JR Joban Railway
Tsuchiura City



JLC * Sites and Civil Engineering

Summary or Plan

Site Study: Proposed A Review by Outside Experts of Various Fields.
(But When?)

Civil Engineering: Continue Case Studies for More Details.

Facility: Revision (for Consistent Estimate for X-band).
Start Case Studies.

(*) Now GLC