TERMS OF REFERENCE

FOR

CONSULTING SERVICES

FOR

CONDUCTING OVERCORING, HYDRO FRACTURING, DILATOMETER, BLOCK SHEAR & PLATE BEARING TESTS WITH RELATED LABORATORY TESTS

IN

UPPER ARUN HYDROELECTRIC PROJECT, NEPAL

INTRODUCTION

Project Description: Upper Arun Hydroelectric Project (UAHEP) is a Peaking Run-of-River (RoR) project with an installed capacity of 1,061 MW, utilising design discharge of 235.4 m^3/s and net head of 508.26 m. The project is located in Bhotkhola Rural Municipality, Sankhuwasabha District of Koshi Province, Nepal. The dam site is located about 70 km north of Khandbari, the district headquarters and 200 km east of Kathmandu. The project is being developed by Upper Arun Hydro-Electric Limited (UAHEL), a company established by Nepal Electricity Authority (NEA).

Project Site: The Project site is located at high altitude in the mountainous area of eastern Nepal, in a narrow gorge approximately 600 m upstream of the confluence of the Chepuwa Khola and the Arun River, which is about 14 km downstream of the Nepalese-Chinese border. The proposed powerhouse site will be about 15 km downstream of the proposed dam site. The Project site covers an area of about 275 ha, containing the proposed headworks, surge tank, powerhouse, roads, camp and associated facilities and spoil areas.

Access to the Site: There is only one route, the Koshi Highway, for transporting goods from Jogbani, Bihar, India, to the Project site, via Biratnagar and Gola. The location of the Project site at high altitude in steep mountainous terrain poses some difficulties for the transportation of large equipment to the Project site by road. The road from Jogbani to Gola is 253 km long and experiences steep gradients and sharp curves, passing through difficult terrain. While most of the bridges along the highway from Jogbani to Gola are deemed safe for transporting up to 80 tonnes of cargo, some will need to be strengthened, notably the Koshi Canal Bridge. Additionally, road improvement will be required, especially at sharp curves. The nearest airport to the Project site is Tumlingtar Airport of Sankhuwasabha district, located south of the Project site. There are regular flights between Kathmandu and Tumlingtar.

Previous Study: The project has completed an Updated Feasibility Study on May 2021, conducted by a joint venture of Changjiang Survey, Planning, Design and Research Co. Ltd. (CSPDR) and Sinotech Engineering Consultants Ltd. in association with Soil Test (P) Ltd. Nepal. During Updated Feasibility Study, the consultant has carried out a wide variety of field studies as part of this Study. The summaries of previous studies are as follows:

Item and content	Unit	Quantities	
		1987 Feasibility Study	1991 Feasibility Study
1:20,000 geological mapping	km^2	22	
1:2,000 geological mapping		1.2	
1:1,000 geological mapping			0.75
Borehole	m/no. of holes	109/4	691.6/11

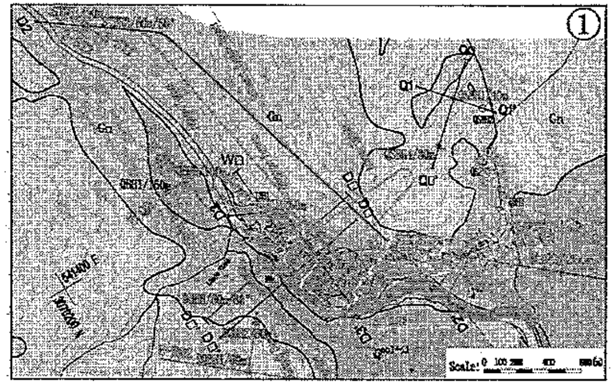
Item and content		Unit	Quantities	
			1987 Feasibility Study	1991 Feasibility Study
Seismic refraction profile		m/ no. of profiles	1,145/10	2,985/7
Lab test	Point load	Number		20
	Uniaxial compression			8
	Brazilian tensile strength			4

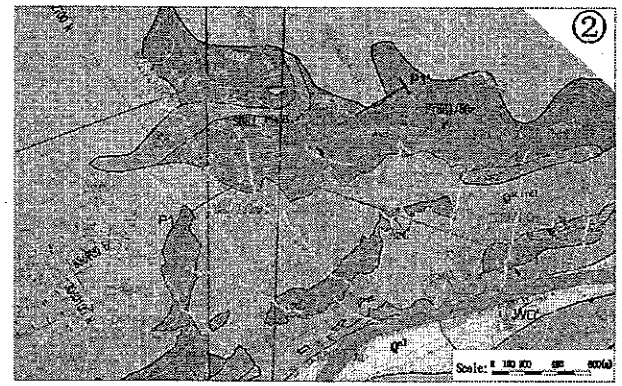
Item and content		Unit	Quantities	Remarks
			2021 Feasibility Study	
Geology	Satellite and drone images interpretation	km^2	117	
	1:5,000 geological mapping	km^2	4.8	Along the headrace tunnel
	1:500 geological mapping	km^2	2.17	Main structures area
	3D geological model	Day	100	
2D-ERT		m/no. of profiles	2,360/13	
Test adit AD1 at the left abutment		m	30	Incomplete (abandoned)
Test adit AD2 at right abutment		m	80	Completed
Test adit AD4 at right abutment		m	103.5	Completed
Test adit AD5 at the powerhouse site		m	786.7/945	As of July 2021
Borehole		m/no. of holes	1,001/12	Including inclined hole 75m/1 hole; Vertical hole 846m/9 hole; Quarry site; 80m/2 hole
Measurement in borehole	Water Pressure	no. of sections/ no. of holes	105/8	
	Acoustic	m/no. of holes	462.4/9	
	Televiewer	m/no. of holes	819.36/10	
	Dilatometer	no. of points / no. of holes	53/3	In borehole DBH5 at dam site, HBH1 at headrace tunnel, and PDBH1 at pressure
	In-situ stress test	no. of points / no. of holes	18/2	In borehole HBH1 and PDBH1, hydro fracture test

Item and content			Unit	Quantities	Remarks
				2021 Feasibility Study	
	Petrographic analysis		Set	15	
	Physical property	Bulk density	Set	16	
		Particle Density	Set	16	
		Moisture Content	Set	16	
		Water Absorption	Set	16	
		Saturation rate	Set	16	
		Porosity	Set	16	
	Mechanical property	UCS	set	15	
		Deformation	set	15	
		Direct shear strength	set	10	
		Tensile strength	set	15	
		Point load strength	set	87	
	Directly shear strength of rock mass joints		set	24	
	Los Angeles Abrasion		set	6	
	Crushing Test		set	3	
	Alkali-Silica Reaction		set	8	
	Water chemical analysis		set	4	

Some investigation works are still not completed with some major in-situ and lab tests. The Upper Arun Hydroelectric Company has signed a contract with Soil, Rock, and Concrete Laboratory (SRCL) in October 2022 to excavate the remaining portion of test adit (AD5) at power house site. It is about 160 m of length of adit remaining to be excavated, and till date, 75 m remaining to be excavated. Likewise, SRCL has also been assigned to drill the borehole PBH4 (430 m), HBH2 (250 m) and TBH1 (180 m), out of which HBH2 is completed and PBH4 and TBH1 will be completed before the start of this service.

Investigations layout for detailed design of UAHEP





Legend

- Alluvium of Quaternary
- Colluvium and Deluvium of Quaternary
- Eluvium and Deluvium of Quaternary
- Precambrian
- Augen Gneiss
- Amphibolitic Gneiss
- Schist
- Gneiss
- Schist with Gneiss
- Boundary of Bedrock and Quaternary (Dotted line is speculation)
- Boundary of Lithology (Dotted line is speculation)
- Fault and Attitude (Dotted line is speculation)
- Suspected lineament (fault) and its No.
- Lower limit of completely and highly weathered
- Lower limit of moderately weathered
- Gneissosity
- Schistosity
- Active Landslide
- Joint survey Point and its No.
- Finished borehole and its No.(in 1987)
- Finished borehole and its No.(in 1991)
- Finished Road borehole and its No. (by Korean company)
- Adit and its No.
- 2D-ERT profile and its No.
- Seismic profile and its No. (in 1987)
- Seismic profile and its No.(in 1991)
- Updated FS Finished borehole and its No.
- Proposed vertical boreholes and its No. , depth for detail design
- Proposed inclined boreholes, its No. , depth and dip angle for detail design
- Proposed 2D-ERT profile and its No. for detail design

नेपाल विद्युत प्राधिकरण
Nepal Electricity Authority

Soil Test (P) Ltd.

PROJECT	TITLE					
UPPER ARUN HYDROELECTRIC PROJECT	Investigations layout for detailed design of UAHEP	VALIDATED				
		APPROVED		Geology	SECTION	
		CHECKED		SCALE	DATE	2019.09
		DESIGNED		SIZE A3	REVISION	A
		DRAWING NO.			SHEET NO.	

OBJECTIVE

The Consulting firm(s) shall provide the service as outlined below:

- Rock Mechanical test including Hydro fracturing, Block Shear, Plate bearing tests, Dilatometer tests, including mobilization, demobilization of all machines & equipment all complete.

- In-situ stress test with over-coring method: two (2) at test adit (AD5) of the Powerhouse (PH) including mobilization, demobilization of all machines & equipment all complete.

SCOPE

1. In-situ stress test by over-coring method

The Consulting Firm(s) shall conduct in-situ stress tests using the over-coring method in test adit (AD5) at the powerhouse by using latest technology such as Borre Probe, Fiber Optic Sensors etc. The purpose of these tests is to determine the in-situ state of stress and stress distribution within the rock mass at the specified test location. The test results will provide valuable information for the design and stability analysis of the underground powerhouse structure.

The main objectives of the in-situ stress tests with over-coring method in test adit (AD5) at the powerhouse are as follows:

a. To determine the magnitude and orientation of the principal stress components within the rock mass.
b. To evaluate the stress distribution and identify potential stress concentrations or anomalies.
c. To provide data for the geotechnical analysis and design of the powerhouse structure.
d. To assess the stability and safety of the rock mass in the vicinity of the test adit.

The consulting firm(s) shall perform the activities including but not limited to the following:

a. Planning and Preparation:

i. Reviewing the geological and geotechnical data for the test adit to identify suitable locations for stress measurement.
ii. Selecting appropriate over-coring equipment and tools based on the rock mass characteristics.
iii. Designing the stress measurement program, including the number and location of test points, and their spacing along the adit.

b. Test Execution:

i. Mobilizing necessary equipment and personnel to the test site.
ii. Preparing the test adit by ensuring a stable and accessible testing surface.
iii. Drilling holes at the selected test points.
iv. Over-coring the rock mass to extract intact samples for stress measurement.

v. Instrumenting the extracted samples with required strain gauges or other suitable stress measurement devices.
vi. Recording the strain readings under no-load and loaded conditions.
vii. Repeating the test at multiple locations along the test adit as specified in the stress measurement program.
viii. Conduct laboratory tests on the core samples to determine their physical and mechanical properties, including but not limited to uniaxial compressive strength, Young's modulus, Poisson's ratio, Ultrasonic Velocity Test.

c. Data Analysis and Interpretation:

i. Analyzing the recorded strain data to determine the in-situ stress components.
ii. Calculating the magnitudes and orientations of the principal stresses.
iii. Assessing the stress distribution and identifying any stress anomalies or concentrations.
iv. Interpreting the test results in the context of the geotechnical analysis and design requirements.

d. Reporting:

i. Compilation and submission of a comprehensive report summarizing the test objectives, methodologies, and results to the UAHEL.
ii. Presenting the analyzed data, including stress magnitudes, orientations, and other relevant findings.
iii. Providing recommendations for the geotechnical analysis and design based on the test outcomes.

2. Block Shear Tests

The Consulting firm(s) shall conduct block shear tests in Test Adit Tunnel (AD5) at the powerhouse. The purpose of these tests is to evaluate the rock mass strength, shear behavior and stability characteristics of rock masses within the tunnel. The test results will provide valuable information for the design and analysis of the tunnel support system.

The main objectives of the block shear tests in Test Adit Tunnel (AD5) at the powerhouse are as follows:

a. To determine the shear strength parameters such as cohesion and friction characteristics of the rock masses within the tunnel.
b. To evaluate the stability of the rock masses under shear loading conditions.
c. To provide data for the design and optimization of the tunnel support system.
d. To assess the potential for rock mass failure or instability within the tunnel.

The consulting firm(s) shall do following activities but not limited to:

a. Planning and Preparation:

i. Reviewing the geological and geotechnical data for the test adit to identify suitable test locations in consultation with UAHEL.
ii. Selecting appropriate block samples for testing based on the rock mass characteristics.
iii. Designing the test program, including the number of tests, sample dimensions, and loading conditions.

b. Test Execution:

i. Mobilizing necessary equipment and personnel to the test site.
ii. Preparing the test adit by ensuring a clean and stable testing surface.
iii. Excavating representative block samples from the rock masses within the tunnel.
iv. Conducting block shear tests on the samples using appropriate shear loading apparatus.
v. Measuring and recording the shear strength parameters, including shear stress and displacement.
vi. Repeating the tests on multiple samples from different locations within the tunnel as specified in the test program.
vii. Collect rock samples for laboratory analysis, including petrographic examination.

c. Data Analysis and Interpretation:

i. Analyzing the recorded data to determine the shear strength parameters of the rock masses.
ii. Assessing the stability of the rock masses based on the test results.
iii. Interpreting the test outcomes in the context of the tunnel/powerhouse cavern design and support requirements.

d. Reporting:

i. Compilation and submission of a comprehensive report summarizing the test objectives, methodologies, and results to the Client.
ii. Presenting the analyzed data, including shear strength parameters, and other relevant findings.
iii. Providing recommendations for the design and analysis of the tunnel/powerhouse support system based on the test outcomes.

3. Hydrofracture/Hydrojacking Test

The Consulting firm(s) shall conduct a hydrofracture/hydrojacking test in borehole PBH4 as shown in the Investigation Layout above. The purpose of this test is to assess the feasibility and effectiveness of hydrofracturing or hydrojacking techniques in the specified borehole. The test will provide valuable information regarding the potential for enhancing fluid flow and serve the objective of identifying an increase in transmissivity of the rock mass with water pressure.

The main objectives of the hydrofracture/hydrojacking test in borehole PBH4 are as follows:

a. To determine the fracture propagation behavior and geometry within the powerhouse area.
b. To assess the effectiveness of the fracturing fluid and the associated injection parameters.
c. To collect data on pressure response, fluid flow rates, and other relevant parameters during the test.

d. To analyze and interpret the data obtained to assess the impact of hydrofracturing/hydrojacking on reservoir performance.

The consulting firm(s) shall do following activities but not limited to:

a. Planning and Design:

i. Reviewing the geological and reservoir data for borehole PBH4 to identify suitable locations for hydrofracturing/hydrojacking.
ii. Selecting appropriate fracturing fluids and proppants (*a gritty material with uniformly sized particles that is mixed in with fracturing fluid during the hydraulic fracturing process to hold open fractures made in the ground*), if needed based on the characteristics.
iii. Designing the fracturing fluid injection program, including fluid volume, injection rates, and pressure limits.

b. Pre-Test Preparations:

i. Mobilizing necessary equipment and personnel to the test site.
ii. Conducting a thorough inspection of all equipment to ensure operational readiness.
iii. Obtaining required permits and ensuring compliance with relevant safety regulations.

c. Test Execution:

i. Rigging up the equipment for the hydrofracture/hydrojacking operation.
ii. Conducting a baseline survey of the borehole and recording initial reservoir conditions.
iii. Monitoring and recording injection parameters, including pressures, flow rates, and volume injected.
v. Conducting real-time pressure transient analysis to evaluate the fracture behavior.

d. Data Analysis and Interpretation:

i. Collecting post-test data, including pressure build-up and flow back information.
ii. Analyzing the data to determine fracture dimensions and conductivity.
iii. Preparing a comprehensive report summarizing the findings and recommendations.

e. Reporting:

i. Compilation and submission of a comprehensive report summarizing the test objectives, methodologies, and results to the Client.
ii. Presenting the analysis of the collected data, including fracture dimensions and conductivity.
iii. Providing recommendations for the geotechnical analysis and design based on the test outcomes.

4. Plate Bearing Test

The Consulting firm(s) shall conduct a plate bearing test in the test adits (AD5) located at the powerhouse. The purpose of this test is to assess the load-bearing capacity and settlement

characteristics of the underlying soil or rock strata in the specified test adits. The test will provide valuable information for the design and construction of the powerhouse foundation.

The main objectives of the plate bearing test in test adits (AD5) at the powerhouse are as follows:

a. To determine the bearing capacity of the rock strata beneath the test adits.
b. To assess the settlement characteristics of the underlying strata under applied loads.
c. To provide data for the design and construction of the powerhouse foundation.
d. To evaluate the suitability of the rock strata for supporting the intended load.

The consulting firm(s) shall do following activities but not limited to:

a. Planning and Preparation:

i. Reviewing the geological and geotechnical data for the test adits to identify suitable locations for the plate bearing test.
ii. Selecting appropriate plate sizes and load increments based on the expected bearing capacity and settlement behavior of the rock strata.
iii. Designing the plate loading test program, including the sequence of loading, duration of each load increment, and the maximum design load.

b. Test Execution:

i. Mobilizing necessary equipment and personnel to the test site.
ii. Preparing the test adits by ensuring a clean, level, and stable testing surface.
iii. Installing the plate load apparatus securely in the test adits.
iv. Applying the specified load increments to the plate and monitoring the settlement response.
v. Recording the applied loads, settlement measurements, and corresponding time intervals.

c. Data Analysis and Interpretation:

i. Analyzing the recorded data to determine the bearing capacity of the rock strata.
ii. Assessing the settlement characteristics and deformation behavior under various load increments.
iii. Interpreting the test results in the context of the powerhouse foundation design requirements.

d. Reporting:

i. Compilation and submission of a comprehensive report summarizing the test objectives, methodologies, and results to the Client.
ii. Presenting the analyzed data, including bearing capacity values, settlement curves, and other relevant findings.
iii. Providing recommendations for the design and construction of the powerhouse foundation based on the test outcomes.

5. Dilatometer Test

The Consulting firm(s) shall conduct dilatometer tests in boreholes HBH2 and TBH1. The purpose of these tests is to determine the in-situ stress-strain characteristics and mechanical properties of the rock strata at the specified borehole locations. The test results will provide valuable information for geotechnical analysis and design.

The main objectives of the dilatometer tests in boreholes HBH2 and TBH1 are as follows:

a. To determine the in situ rock properties, including the elastic modulus, shear strength, and stress-strain behavior.
b. To evaluate the lateral stress coefficient and the coefficient of earth pressure at rest.
c. To provide data for the geotechnical analysis and design of structures in the vicinity of the boreholes.
d. To assess the ground conditions and identify potential geotechnical hazards or limitations.

The consulting firm(s) shall do following activities but not limited to:

a. Planning and Preparation:

i. Reviewing the geological and geotechnical data for the boreholes to identify suitable testing depths and intervals.
ii. Selecting appropriate dilatometer equipment and tools based on the expected rock conditions.
iii. Designing the dilatometer testing program, including the depth intervals, number of tests, and test spacing.

b. Test Execution:

i. Mobilizing necessary equipment and personnel to the test site.
ii. Preparing the boreholes by ensuring a clean and stable testing surface.
iii. Inserting the dilatometer probe into the boreholes and applying the required pressure cycles.
iv. Measuring and recording the dilation and pore pressure responses at various depths.
v. Repeating the test at multiple depths and locations as specified in the testing program.

c. Data Analysis and Interpretation:

i. Analyzing the recorded data to determine the rock properties, including the elastic modulus, shear strength, and stress-strain behavior.
ii. Calculating the lateral stress coefficient and the coefficient of earth pressure at rest.
iii. Interpreting the test results in the context of the geotechnical analysis and design requirements.

d. Reporting:

i. Compiling a comprehensive report summarizing the test objectives, methodologies, and results.
ii. Presenting the analyzed data, including soil or rock properties, stress-strain curves, and other relevant findings.
iii. Providing recommendations for geotechnical analysis and design based on the test outcomes.

HEALTH, SAFETY, AND ENVIRONMENT (HSE)

The safety of all personnel involved in the services is of paramount importance. The testing program of the project must be conducted in compliance with all relevant safety regulations, and appropriate safety measures throughout the test duration. An HSE plan should be developed and strictly adhered to.

REQUIRED EXPERTISE OF CONSULTANT'S PERSONNEL

The Consultant's experts shall include a team of international and national experts with extensive experience of geological and geotechnical investigations including all tests as per scope of work. The members of the team shall have the skills and experience necessary to undertake the range of tasks set out in these Terms of Reference. The key personnel shall come from the fields of expertise described below and be preferably not a freelancer but an employee of the Consultant.

1. **Team leader / Geotechnical Engineer:** A geotechnical engineer shall specialize in studying the behavior of soil and rock materials. S/he shall play a crucial role in planning and executing proposed tests, selecting appropriate test locations, and ensuring the safety and integrity of the test location. S/he shall also provide expertise in interpreting the test results and assessing the geotechnical properties of the rock mass. The Geotechnical Engineer should work as the team leader and shall be responsible to manage overall services, coordinate and report to the Client frequently.

The Geotechnical Expert shall have a Master's degree in geotechnical engineering or equivalent discipline and must have at least 20 years of professional experience in conducting geotechnical investigations and studies for dams and underground works.

2. **Engineering Geologist:** An engineering geologist shall provide geological expertise, including the identification of rock types, structures, and potential geological hazards. S/he shall assist in selecting suitable locations test and provide context for understanding the geological conditions that may influence the test results.

The Engineering geologist shall have minimum of Master's degree in engineering geology, or equivalent and must have at least 10 years of professional experience in conducting engineering geological investigations studies for dams and underground works.

3. **Data Analyst:** A data analyst is responsible for processing and analyzing the data obtained from the proposed tests and laboratory testing. S/ he shall use statistical and analytical methods to interpret the data, identify trends, and extract meaningful information. His/her expertise helps in drawing conclusions and making recommendations based on the test results.
4. **Laboratory Technician:** A laboratory technician shall perform various tests on the extracted samples. S/ he shall have expertise in sample preparation, testing procedures, and operating

laboratory equipment. They shall play a critical role in conducting standardized tests to determine the physical and mechanical properties of the rock samples.

SERVICES AND FACILITIES BY UAHEL

Documentation: UAHEL shall provide all relevant available documents, including reports on previous studies that may be required for the performance of the services.

General Assistance: UAHEL shall provide the assistance in obtaining working permits, residence visas, exit, re-entry and exit visas for the Consultant's staff, other licensing documents, etc. UAHEL shall also provide the assistance in facilitating and expediting customs procedures in connection with importation and re-export (as needed) of equipment and materials necessary for the Consultant's services and for the personal use of the Consultant's staff.

Office space/Residence, facilities, and transportation: Office and living space at site including maintenance will be provided by the Client. Office space/ Guest house at Kathmandu will be rented by the Consultant. The Consultant will rent the necessary numbers of vehicles for the entire period of service.

Counterpart Staff

UAHEL will supply technical personnel to assist with the project's tasks. The Consultant's responsibilities include, but are not limited to, the following activities:

- Engaging UAHEL's technical staff from the project's outset for on-the-job training at the site;
- Offering on-the-job training to UAHEL personnel while working on assignments in Kathmandu/site.

The UAHEL will cover all costs associated with the on-the-job training. The consultant will not be responsible for any expenses related to the counterpart staff.

IMPLEMENTATION TIME SCHEDULE AND EFFORT LEVEL

The Consultancy Services shall be undertaken and completed within a period of 2 months and the effort level of Key/Non-key Experts (International/National) for the assignment is estimated at 9 staff-months (indicative) covering all Tasks described above.

The staff-month estimates are indicative and the Consultant is free to propose improvements to the Terms of Reference and the schedule in its technical proposal. The Consultant shall propose a detailed staffing schedule appropriate for the provision of the required consultancy services.

DELIVERABLES

Consultant shall provide following documents to the Client:

1. Hard copy of test report including all tests performed as per scope of services with relevant photographs, backup calculations and result - 5 copies.
2. Soft copy of the report – in USB device.

PAYMENT SCHEDULE

The payment to the consulting service will be as follow:

S.N	Milestones/ Stages	Percentage of Total Contract Amount	Remarks
1	Mobilization and Preparation	15%	Initial stage involves mobilizing the overcoring machine and all other necessary equipment and personnel to the project site and preparing for the in-situ tests
2	Data Collection and Testing	40%	Includes conducting the actual in-situ tests and collecting the relevant data
3	Laboratory Analysis and Reporting	20%	the laboratory analysis of rock samples and test results are carried out to determine the stress and other relevant parameters
4	Quality Assurance and Additional testing (if required)	5%	Additional testing or quality assurance measures may be necessary to validate the results or address any concerns
5	Final Payment	20%	Involves the completion of all contractual obligations, including the submission of all required documentation and final reports