



NORTHLIGHT
POWER

FIRST EDITION

Natural Hydrogen Equipment Handbook

Detailed summary of Volumes I and II

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READING GUIDE

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Geology, measurement methods and commercial equipment.

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OVERVIEW

Overview

The Natural Hydrogen Equipment Handbook, prepared by Chapman Hydrogen and Petroleum Engineering Ltd. (CHAPENG) and circulated by Denis Brière, describes how naturally occurring hydrogen is detected, measured and investigated during exploration. It brings together the geological context, field methods and commercial instrumentation used to identify hydrogen occurrences and assess their significance.

Volume I explains exploration principles, survey design, sampling procedures, equipment selection and quality control. Volume II reviews 50 manufacturers and compares their products by measurement principle, application, operating requirements and cost. The two volumes connect the scientific questions being investigated with the practical methods and equipment available to investigate them.

Principal themes

A central theme is that a hydrogen reading gains meaning from its context: where and how the sample was collected, whether the result is repeatable, what other gases are present and how the observation relates to the geology. The handbook therefore treats exploration as a combination of geological interpretation, complementary measurements and controlled field practice.

The proposed sequence moves from regional screening to systematic sampling, detailed target definition, continuous monitoring and borehole appraisal. Each stage addresses a more specific uncertainty. Atmospheric, soil-gas, groundwater and surface-flux measurements provide different views of the system; compositional analysis and subsurface testing add evidence about its origin, continuity and potential recovery.

Equipment selection follows the measurement task. The handbook combines selective low-level analysis, rugged field instruments, higher-range measurement, gas-composition analysis and independent safety monitoring. It also examines the sampling systems, calibration, data handling, power, service and operating costs that allow those instruments to function together.

Throughout both volumes, hydrogen's presence, the explanation for its occurrence and its potential for sustained recovery remain related but separate questions. Continuing generation is considered a possibility in some geological systems; persistence, replenishment and deliverability are matters for investigation.

Source: Volume I, foreword, preface and Chapters 1-2, 9-12; Volume II, Sections 6A.1 and 6A.8. This document summarizes the supplied drafts and their conclusions; it does not independently verify product specifications or assess a particular resource.

01 / GEOLOGY & MEASUREMENT

The geological hydrogen system

Volume I introduces natural, or white, hydrogen as molecular hydrogen occurring within the Earth. Its geological model combines generation, movement, accumulation and loss. The presence of suitable source rocks is one part of that model; water availability, reaction conditions, connected pathways and the ability to retain gas also influence the outcome.

Generation mechanisms

Serpentinization involves water reacting with ultramafic rocks, which are rich in magnesium and iron. Changes in iron's oxidation state during mineral alteration can release hydrogen. The handbook relates this mechanism to ultramafic bodies and ophiolites, where rocks originally formed in oceanic settings are exposed on land. Other reactions involving iron-bearing minerals and water are also discussed.

Radiolysis is the splitting of water molecules by energy from natural radioactive decay. The handbook considers it relevant to crystalline rocks containing radioactive elements and to long-lived groundwater systems. It distinguishes these processes from proposed deep mantle contributions, whose significance remains an active research question, and from local biological generation.

Migration, reservoirs and retention

Hydrogen can move by diffusion, by pressure-driven fluid flow and through faults or fractures. It may travel with other gases or dissolve in groundwater. Fault intersections, permeable formations and fracture networks therefore help define where observations might be expected. A mapped structure provides a possible pathway, while field evidence tests whether hydrogen is actually moving through it.

Accumulation requires suitable storage space and conditions that restrict escape. The handbook considers porous or fractured reservoirs, seals and structural or stratigraphic traps. In some systems, ongoing generation or replenishment may offset leakage. That possibility changes the questions asked during appraisal, including whether measured gas persists and how the system responds over time.

Consumption and the surface expression

Hydrogen can be consumed by microorganisms, react with minerals or escape into the atmosphere. Soil conditions and groundwater can alter or redistribute its near-surface expression. As a result, an observation may be displaced from its source, reduced before reaching the surface or concentrated temporarily in a particular sampling medium.

These characteristics explain the handbook's emphasis on multiple lines of evidence. Geology suggests mechanisms and pathways; gas and water measurements test their expression; time-series observations examine variability; and borehole investigations address conditions at depth. The strength of an interpretation depends on how these observations fit together.

Source: Volume I, Chapters 1-2 and Chapter 13, especially Sections 13.3-13.6.

02 / GEOLOGY & MEASUREMENT

What the measurements mean

Concentration, flux and flow

Concentration expresses the proportion of hydrogen in a sample. Gas results may be reported in parts per billion (ppb), parts per million (ppm) or percent by volume; 1% equals 10,000 ppm. Dissolved-gas results can instead be expressed as a mass per volume of water. Comparisons depend on consistent units and on whether measurements describe the original sample or gas extracted from it.

Surface flux is the amount of hydrogen crossing a defined area per unit time. Well flow is the quantity of gas delivered over time under specified conditions. Neither is established by concentration alone. A high hydrogen fraction in a small gas sample supplies different information from a sustained rate measured during a well test.

Sensitivity, selectivity and background

Sensitivity describes an instrument's response to small changes; selectivity describes its ability to distinguish hydrogen from other influences. The handbook separates display resolution from a demonstrated detection limit, and detection from reliable quantification. A result below a method's reporting limit is recorded with that limitation, rather than automatically treated as zero.

Background is assessed within the local geological and environmental setting. Soil type, water conditions, weather and human activity can all affect readings. An anomaly is therefore an observation distinguishable from relevant background with a valid method, rather than any reading above a universal numerical threshold.

Why associated gases and water chemistry matter

	Measurement	Interpretive contribution in the handbook
	Helium	Provides context for crustal or deeper fluids and migration pathways. Its presence alone does not establish a hydrogen-generation mechanism.
	Methane and carbon dioxide	Help characterize mixed-gas systems, microbial processes, hydrocarbon associations and potential alternative sources.
	Oxygen and nitrogen	Help evaluate air dilution, sampling leaks, gas balance and chemical conditions.
	Carbon monoxide, hydrogen sulfide and organic vapours	May reveal interfering responses, contamination, reducing conditions or operational hazards.
	Water chemistry	pH, oxidation-reduction conditions, conductivity, dissolved oxygen and selected ions provide context for water-rock reactions and hydrogen preservation or consumption.

Source: Volume I, Chapters 2 and 5; Sections 11.10, 11.18 and 12.7; Volume II, Sections 6A.3-6A.4 and Appendix C.

Atmospheric and mobile surveys

Purpose and survey configuration

Atmospheric surveys draw air into an analyzer from a fixed intake or a moving platform. Vehicle surveys provide regional coverage; walking and backpack systems allow closer investigation where road access is limited. The principal objective is to locate repeatable hydrogen patterns that can guide more detailed work.

The handbook's typical system combines a hydrogen analyzer, inlet and pump, positioning, weather measurements, power and continuous data recording. Supporting gas channels can help characterize mixed emissions. Survey routes cross geological structures and include background areas, reducing the risk that the map reflects road access or infrastructure alone.

Weather, timing and source attribution

Wind and atmospheric mixing influence the position and strength of an observed plume. A measured peak may occur downwind of a release, and different weather can produce different readings at the same location. Nearby combustion, vehicles, facilities and other potential sources are recorded so that they can be considered during interpretation.

The sampling line introduces a delay between collection and detection. During a moving survey, an uncorrected delay can shift the apparent location of an anomaly. The handbook therefore links hydrogen readings to synchronized position and weather records and evaluates the response of the full inlet, tubing and analyzer system. Instrument response speed also affects whether a narrow feature is resolved or smoothed.

Repeat passes and continuous stations

Repeated transects and stationary background checks establish whether a pattern is reproducible. The handbook places more weight on spatially coherent features and repeated observations than on isolated peaks. Calibration, pump flow, power and instrument status accompany the gas record so that equipment events can be distinguished from environmental changes.

Continuous stations extend the observation period across daily, weather-related and seasonal variation. Pairing an anomaly station with a comparable background station helps distinguish local behaviour from wider environmental changes. A correlation with pressure or rainfall can help explain a signal without, by itself, proving or disproving a geological source.

Airborne and drone methods

Airborne platforms can extend access and coverage, but deployment introduces constraints involving payload, power, wind, aircraft airflow and sample timing. The handbook distinguishes collecting air for later analysis from measuring it with an onboard analyzer. Both require a documented link between the sample, its location and the conditions under which it was collected.

Source: Volume I, Chapters 3 and 7; Sections 11.4, 11.6 and 11.14-11.15; Chapter 14 for the drone technology outlook.

Soil gas and surface flux

Soil-gas sampling

Soil-gas surveys use probes to collect gas below the surface. Compared with atmospheric measurements, they offer a more localized view of possible seepage and can resolve gradients around faults, contacts, springs and other features. The observed concentration reflects both gas supply and the conditions within the soil.

Sampling geometry is therefore important. Probe depth, sealing, soil disturbance, tubing volume, pumping rate and the time allowed for readings to stabilize influence the sample. Residual air in the equipment is removed through a controlled purge. Excessive suction or a poor seal can draw in outside air and dilute the gas; water in the line can interrupt flow or change the response.

The handbook combines standardized measurements with repeat stations, blanks, duplicates and selected gas-tight samples for independent analysis. Dense follow-up sampling is concentrated around coherent patterns. Soil moisture, texture, permeability, temperature and biological activity help explain why concentrations differ between nearby points or between campaigns.

Flux-chamber measurements

An accumulation chamber encloses a known area of ground. The change in hydrogen concentration over a measured period is used to estimate flux, accounting for chamber volume and area, temperature, pressure and the measurement configuration. The time trend provides information about gas movement through the surface that a single concentration reading cannot supply.

Chamber placement can itself disturb the process being observed. Sealing, insertion depth, mixing, sample circulation and pressure differences affect the result. The measurement interval also matters: it must resolve a meaningful trend while accounting for changes such as heating, leakage or a non-linear concentration response. The handbook includes chamber blanks, leak checks and repeat placements within the method.

Interpreting the methods together

Soil concentration and surface flux describe different aspects of the same near-surface system. Their agreement or disagreement becomes a subject for interpretation alongside soil properties, groundwater and geological structure. The handbook uses co-located measurements to examine whether a concentration pattern is associated with active surface transfer and whether the relationship persists.

Neither method independently establishes reservoir size or recoverable production. Their main contribution is to characterize where hydrogen is observed, how it moves at the surface and whether that pattern supports a wider geological explanation. Repeat work under documented environmental conditions makes comparisons more meaningful.

Source: Volume I, Chapters 4 and 6; Sections 11.7-11.9 and 12.9-12.10.

Groundwater and dissolved hydrogen

What groundwater adds

Groundwater provides a subsurface sampling medium that can preserve evidence of hydrogen migration where surface seepage is weak or absent. Wells, exploration boreholes and springs provide access to different depths and flow systems. The handbook treats water measurements as an independent dataset that can support, refine or complicate the interpretation of soil and atmospheric anomalies.

Existing domestic wells offer accessible sampling points, but construction details, pumping history and possible contamination may be uncertain. Monitoring wells and exploration boreholes provide more controlled information about the interval being sampled. Springs can reveal fluid discharge along structures, although the water's route to the surface remains part of the interpretation.

Preserving the sample

Hydrogen can be lost during pumping, open transfer, pressure changes or storage. Microbial and chemical reactions can also change a sample after collection. The handbook describes low-disturbance pumping, stabilization of water-quality readings, closed collection and containers validated for gas retention. Sample history and time to analysis are therefore relevant to the reported result.

Transferring dissolved gas into an analyzer

Headspace analysis uses a sealed container and a known gas and water volume. After controlled equilibration, the gas phase is analyzed and the original dissolved concentration is calculated using the method's partitioning assumptions. Temperature, pressure and sample composition affect that calculation.

Membrane extraction transfers dissolved gases across a membrane into a measurable stream, while vacuum extraction releases gas through controlled pressure reduction. Membrane-inlet mass spectrometry is also discussed for advanced and research applications. These methods differ in continuity, complexity and sample handling, but all require validation of the complete water-to-measurement pathway.

Hydrochemistry and interpretation

Measurements of pH, oxidation-reduction potential, dissolved oxygen, conductivity, temperature, alkalinity and selected ions provide context for hydrogen generation and consumption. Iron chemistry, sulfate and sulfide can help characterize water-rock and microbial processes. Associated gases, including methane and helium, add further information about the fluid system.

The quality framework includes blanks, duplicates, laboratory controls, documented preservation and chain of custody. Changes through time are interpreted alongside groundwater level, flow direction and seasonal conditions. A water result is consequently understood as part of a hydrological system, rather than simply mapped as a point directly above a gas source.

Source: Volume I, Chapter 5; Sections 11.7, 11.10 and 12.11; Volume II, Sections 6A.4-6A.5.

From reconnaissance to appraisal

Chapter 11 sets out six survey levels, numbered 0-5. The sequence moves from broad hypotheses toward increasingly direct tests of the subsurface system. Progress depends on what the evidence resolves and what remains uncertain.

Level 0: Geological and operational screening

Existing geology, geophysics, well records and gas observations are assembled into a model of generation, migration and retention. Competing sources, access, seasonal constraints and the quality of historical evidence are considered. The outcome is a set of testable targets and a feasible field program.

Level 1: Regional reconnaissance

Rapid atmospheric surveys, targeted soil-gas points and background observations identify candidate patterns. Follow-up depends on repeatability, spatial coherence, valid instrument checks and geological plausibility. An isolated spike remains an observation requiring investigation.

Level 2: Systematic investigation

Structured grids and transects combine soil gas, flux, groundwater, associated gases and geological observations. The handbook classifies evidence from high-confidence anomalies to ambiguous or low-confidence results. Missing confirmation, weather effects and potential contamination influence the classification and the subsequent work.

Level 3: Detailed target definition

Closer sampling, structural mapping, hydrogeology, selected geophysics and composition analysis test a specific mechanism and refine possible drill locations. The handbook's target-ranking framework considers reproducible hydrogen, selective confirmation, agreement between sampling media, generation, migration, retention and operational feasibility.

Level 4: Continuous and seasonal monitoring

Priority targets are observed across relevant weather and seasonal conditions. Matched background stations, groundwater information and equipment-status records help distinguish persistent behaviour, periodic changes and short-lived events. Gaps and maintenance intervals remain visible in the time series.

Level 5: Borehole investigation and appraisal

Drilling, formation evaluation and well tests introduce depth, pressure, temperature, gas composition and flow measurements. Sampling delays, drilling disturbance and gas-handling conditions affect interpretation. Appraisal examines whether the subsurface gas persists and can be delivered under controlled conditions, including its time-dependent behaviour and impurities.

The sequence is accompanied by documented review points rather than one universal concentration threshold. Survey density and analytical effort increase as a target becomes better supported. Geological, spatial, analytical and temporal evidence remain linked through a common data record.

Source: Volume I, Chapter 11, Sections 11.1-11.22. The levels and confidence categories are the handbook's proposed framework.

Measurement quality and data integrity

The complete measurement method

The handbook evaluates the analyzer together with its probe, pump, tubing, filters, extraction equipment, containers and processing. A precise detector can still produce a biased result if gas is lost, diluted, contaminated or delayed before measurement. The field detection and quantification limits therefore belong to the complete method.

Calibration, blanks and independent checks

Calibration uses known gas standards over the relevant concentration range. The gas mixture, humidity, pressure, flow and delivery arrangement are considered alongside the analyzer. Zero checks test the baseline; span checks test response at known concentrations; independent standards can reveal bias that the calibration source itself would not expose.

Blanks examine contamination associated with equipment, field handling or transport. Duplicates assess repeatability, while repeat stations also capture local spatial variation. Selective confirmation by gas chromatography or another validated method examines whether an apparent hydrogen response is supported independently. The handbook includes representative background samples as well as significant anomalies in confirmation work.

Interference and environmental response

Validation considers gases and conditions likely to occur in the actual sample, including methane, carbon monoxide, hydrogen sulfide, moisture, oxygen, temperature and pressure. Sensor age, contamination and exposure to high concentrations can affect later readings. A change in configuration or sampling materials may therefore require renewed checks.

Records, failures and uncertainty

Each result is linked to a station, sample, instrument configuration, time, location and calibration history. Chain of custody documents collection, transfer and laboratory receipt. Raw values, processed results, environmental records and interpretation are retained with their relationships intact.

The handbook provides categories for accepted, qualified, estimated, contaminated, repeat-required and rejected data. Failed controls trigger investigation and a documented decision about the affected interval. Non-detects retain their reporting limits, and missing periods are distinguished from measured values. Maps and averages are interpreted with the underlying sampling coverage and uncertainty visible.

Safety measurements

Analytical instruments and certified personal or area detectors have separate functions. Scientific measurements characterize the gas system; safety equipment supports alarms and protection under its approved configuration. A safety bump test checks response and alarm operation, while analytical calibration establishes measurement performance. The handbook preserves that distinction throughout field, borehole and facility work.

Source: Volume I, Chapter 12 and Sections 11.17-11.18; Volume II, Sections 6A.1, 6A.3 and 6A.7.

08 / EQUIPMENT & OPERATIONS

Detection technologies compared

The handbook compares the physical sensing principle before assessing the particular instrument. Range, selectivity, response, drift and the surrounding gas mixture determine how useful a measurement is. The same broad technology can appear in instruments designed for very different tasks.

Technology	Operating principle, role and limitations
 Electrochemical sensors	A reaction produces an electrical signal related to gas exposure. These sensors are used in portable and fixed instruments. Cross-response to other gases, environmental effects and sensor life are evaluated for the exact hydrogen cell.
 Catalytic sensors	Combustible gas reacts at a heated element, changing its temperature or resistance. Common in safety and higher-range instruments. Response is generally not unique to hydrogen; oxygen availability and catalyst contamination affect performance.
 Thermal conductivity	Hydrogen changes heat transfer relative to a reference gas. Useful in higher-concentration or process streams and as a detector after gas separation. A changing mixture can bias an unseparated measurement.
 Palladium and other hydrogen-specific solid-state systems	Hydrogen interaction with a sensing layer changes an electrical property. The handbook emphasizes fixed and process applications. Useful range, contaminants, temperature effects and recovery remain product-specific.
 Metal-oxide, semiconductor and miniature sensors	Surface interactions alter electrical or thermal properties. Compact devices support portable instruments and custom networks. Drift, humidity, cross-sensitivity and the electronics and software of the complete instrument determine field performance.
 Direct optical hydrogen analysis	A documented optical method measures hydrogen selectively. Relevant systems support fast measurements and digital integration. The optical or laser label alone does not establish a hydrogen channel, its sensitivity or its suitability for a particular task.

A distinction within optical equipment

Volume II explicitly distinguishes validated direct-hydrogen methods from optical channels measuring methane, carbon dioxide, water vapour or other supporting gases. Conventional infrared hydrocarbon detection cannot simply be treated as hydrogen measurement. The detailed configuration and evidence for the hydrogen channel control the comparison.

Separation and reference analysis

Gas chromatography separates sample components before detection; mass spectrometry characterizes gases through ion measurement. These methods add composition and independent confirmation. Their capabilities depend on configuration, calibration and sample handling, and their field practicality differs from that of continuous survey instruments.

Source: Volume II, Section 6A.4, especially 6A.4.2-6A.4.11; Volume I, Chapters 8-9.

Volume II: Field equipment findings

The 50 manufacturer reviews follow a common 16-part structure. They examine products, measurement principles, performance, strengths, limitations, deployment, calibration, data, maintenance, certification, purchase cost and five-year ownership cost. The comparative ratings describe suitability for a stated role; products in different categories are not treated as interchangeable.

LI-COR: Direct hydrogen measurement

The LI-7835 review emphasizes direct hydrogen measurement alongside methane and water vapour, rapid data output and integration with mobile or stationary sampling. The accompanying channels provide mixed-gas and moisture context. The review also makes a specific distinction: published precision at an elevated hydrogen concentration does not establish the field detection limit near atmospheric background. Low-level performance remains a separate validation question.

New Cosmos, RKI/Gastech and GMI: Portable range coverage

New Cosmos is highlighted for a portfolio extending from low-level localization to pumped field measurements and high-concentration gas analysis. RKI's EAGLE family and GMI's hydrogen Gasurveyor platform combine configurable hydrogen, combustible-gas and other channels. Their range coverage is relevant to soil gas, strong anomalies, boreholes and wellhead investigations, but the installed sensing principle and gas mixture govern interpretation.

QED/Geotech and GfG: Field survey platforms

The handbook discusses pumped, multi-gas instruments that can support repeatable field sampling. In the QED/Geotech review, a dedicated hydrogen option is distinguished from a carbon-monoxide channel compensated for hydrogen interference. This illustrates why a product's model family or a reference to hydrogen in its documentation is insufficient to establish what it actually measures.

INFICON and ION Science: Different roles within a portfolio

INFICON's hydrogen leak-localization products and its micro-GC composition system perform different jobs. Rapid localization can identify a concentrated release or a leak in sampling equipment, while chromatography provides separated gas measurements. A leak-rate or locator response is not automatically equivalent to ambient geochemical concentration.

ION Science provides a similar distinction: its reviewed thermal-conductivity leak detectors have a hydrogen-relevant localization role, while its photoionization instruments measure organic vapours rather than molecular hydrogen. Those supporting measurements may still help identify contamination or hydrocarbon context.

Source: Volume II, Reviews 1-5, 14-15 and 17-18; Sections 6A.3 and 6A.8. LI-COR's detection-limit qualification appears on PDF page 34. Supplier descriptions report the handbook's assessments, not current product endorsements.

Laboratory, process and supporting systems

Chromatography and composition analysis

Gas chromatography separates hydrogen from other gases before measurement. This is particularly relevant where methane, nitrogen, oxygen, carbon dioxide, helium and other components occur together. Columns, detectors, carrier gas, sample injection and calibration determine the actual hydrogen method; the presence of a gas chromatograph alone does not define its sensitivity or suitability.

The handbook discusses INFICON and Agilent for field or micro-GC applications, and Agilent, Shimadzu, SRI and other suppliers for laboratory confirmation. Chromatotec contributes automated chromatographic systems. Portable and mobile-laboratory configurations can shorten sample transport and turnaround, while fixed laboratories offer controlled conditions and analytical flexibility. Each carries requirements for standards, consumables, operator skill and method control.

Fixed and process measurement

H2scan is positioned around direct hydrogen measurement in conditioned sample streams, fixed stations and borehole-head or test systems. Broader process portfolios, including ABB, Siemens, Yokogawa, Emerson, Servomex, AMETEK, HORIBA, Fuji and SICK, support selected high-range, compositional or continuous duties. These are engineered installations whose sample conditioning, pressure, moisture, power and data interfaces form part of the system.

Specialist source-rock analysis

Vinci's Hydrogen-Eval is described as a laboratory method for investigating hydrogen-generation potential. Rock samples undergo controlled thermal and atmospheric programs, including different conditions for organic matter and iron-rich rock reactions. The output concerns experimental generation and kinetics. It supplies evidence about possible mechanisms, rather than directly measuring an in-situ gas accumulation, surface flux or producible resource.

Sensors, safety and complementary measurements

Original equipment manufacturer (OEM) suppliers such as Figaro, City Technology, Membrapor, Alphasense, Winsen, SGX, Nissha FIS and SemeaTech provide components for larger instruments. Their sensor specifications do not establish the performance of the completed device. Nissha's review also includes a compact chromatographic system, illustrating that a supplier can span several roles.

Dräger, MSA, Honeywell, Industrial Scientific, Crowcon, Teledyne and Blackline contribute safety and monitoring platforms. Oxygen, moisture and other supporting measurements assist sample-quality or operating interpretation. Borehole diagnostics such as pressure, temperature and integrity tools provide additional context, but are distinguished from direct hydrogen or composition analysis.

Source: Volume II, Reviews 3, 6-11, 20-28 and 33-50; Sections 6A.3-6A.4 and 6A.8. ROKE-type diagnostics are discussed as a complementary category in the synthesis.

The five exploration equipment packages

Chapter 10 translates individual instruments into complete field packages. These include sampling hardware, positioning, weather records, data systems, power, communications, calibration supplies and independent safety equipment. Their scope increases with the investigation rather than with instrument count alone.

	Package	Function and principal additions	Handbook capital estimate
	1. Regional reconnaissance	Rapid mapping, targeted soil-gas sampling, background checks and basic field support.	US\$100,000-300,000
	2. Systematic field exploration	Adds stronger trace capability, repeatable field coverage, flux, groundwater and selective confirmation.	US\$400,000-1 million
	3. Advanced integrated exploration	Combines multiple teams, continuous stations, hydrogeology, selected geophysics and an operations base.	US\$1.5-4 million
	4. Borehole and appraisal monitoring	Engineered sampling, pressure and gas conditioning, composition, flow, data and site safety systems.	US\$2-7 million; drilling excluded
	5. Mobile laboratory and research	Brings analytical confirmation, preparation, calibration and specialist investigation closer to the field.	US\$1.5-5 million

These are the handbook's indicative planning estimates, not current quotations or project budgets. The stated bands exclude land access, permitting, drilling, aircraft, long-term salaries and major civil works unless specifically included. Package 4 also excludes the rig, well construction, completion, stimulation and major production facilities.

How the packages are intended to develop

The handbook presents Package 2 as an operating baseline for a professional explorer because it combines mapping with several means of confirmation. Package 1 remains an option for a short screening campaign or staged proof of concept. Advanced stations and integration are added as prospects mature, while borehole systems correspond to drilling and appraisal requirements.

A mobile laboratory serves a different purpose from increasing survey coverage: it reduces analytical turnaround and brings sample handling and quality control closer to field decisions. The handbook relates ownership to analytical workload and the value of rapid confirmation, and discusses contracting specialist laboratory or geophysical services during earlier stages.

The common requirement

All packages depend on the components working together. The handbook includes complete-system acceptance, synchronized records, reliable power, consumables, service and field competence within the package definition. Expanding a program therefore involves operating capacity and data quality as well as additional instruments.

Source: Volume I, Chapter 10; capital bands in Section 10.1, printed page 83 / PDF page 84. Volume II, Section 6A.6, provides related packages by application and scale.

Procurement, operation and ownership cost

Defining what is being supplied

The procurement framework starts with the intended measurement, sample mixture, concentration range and field conditions. It then identifies the exact sensor, pump, accessories, firmware, software and certification. The handbook treats family-level descriptions as insufficient where product options materially change hydrogen response or operating suitability.

A complete scope includes the analyzer and its sampling, power, data and calibration arrangements. For fixed installations, it can also include shelters, pressure reduction, liquid removal, filtration, controlled venting and integration with other systems. Installation and commissioning can consequently represent a substantial part of the total requirement.

Acceptance and field validation

The described sequence begins with configuration and documentation checks, followed by response, leak, flow, range and recovery tests. Representative gas mixtures and environmental conditions examine interference and operating limits. A field pilot then evaluates the actual sampling train, reference comparisons, data capture and practical reliability.

Performance is considered against defined acceptance criteria. The handbook's assessment includes the ability to recover after high exposure, retain useful data during operational interruptions and reproduce results across instruments or crews. A successful power-on or a nominal specification is not treated as evidence that the full field method has been demonstrated.

Five-year ownership cost

Volume II considers acquisition, sampling accessories, calibration standards, carrier gases, consumables, replacement sensors, batteries, maintenance, software, training, freight and downtime. A low-cost sensor can require substantial development of its enclosure, electronics, compensation and calibration system. A more complex analyzer may require specialist service, controlled conditions and greater operator support.

The reviews therefore connect analytical capability to regional service access, repair turnaround, spare parts and the expected useful life of the equipment. Planning estimates depend on their scope, currency and configuration; the handbook identifies current quotations and manufacturer documentation as the controlling procurement evidence.

Data and field continuity

Raw-data export, timestamps, diagnostic records, offline operation and software terms are assessed separately from analytical performance. Remote stations also need local storage and a way to reconcile data after communications outages. Battery capacity, start-up demand, environmental control and backup power affect how much valid monitoring time is obtained.

Source: Volume I, Chapters 8 and 10; Volume II, Sections 6A.1.6-6A.1.8, 6A.3 and 6A.7-6A.8.

Geological settings and survey emphasis

Chapter 13 connects geological mechanisms to the expected sample, companion gases and environmental complications. The same detector can face materially different conditions across settings, so the handbook adapts the broader measurement program as well as the instrument.

Canadian Shield and crystalline cratons

Radiolysis, iron-bearing minerals, deep fracture waters and mafic or ultramafic bodies are considered alongside long-lived basement structures. Soil cover and glacial deposits can weaken or displace the surface expression. The approach combines fracture-related gas observations, groundwater, structural mapping and selected magnetics or electrical methods. Surface anomalies are interpreted with overburden and groundwater movement in mind.

Sedimentary basins

Hydrogen may occur in reservoir gas or formation water and move along faults or unconformities. Hydrocarbons, wells, pipelines and industrial activity create alternative sources or interfering signals. The handbook emphasizes gas composition, infrastructure context and the relationship between shallow observations, deeper water and borehole measurements.

Ophiolites and ultramafic rocks

The geological model centres on water-rock reactions, alteration and available pathways. Alkaline waters, methane and mineral changes can accompany the system. The described program combines broad concentration coverage, spring and water chemistry, mineralogical work and compositional confirmation, accounting for steep gradients and potentially strong local gas.

Rifts and major faults

Deep structures may focus fluids from several levels. Seepage can be narrow, episodic or weather-responsive, so repeated fault-crossing surveys and paired anomaly/background monitoring are important. Associated gases, geophysics and structural observations help assess competing explanations for the fluid source and movement.

Salt, volcanic and hydrothermal settings

Salt basins introduce brine chemistry, corrosion and possible sealing or cavern relationships. Volcanic and hydrothermal settings add steam, heat and complex gas mixtures, potentially including toxic or corrosive components. Cooling, boiling and phase separation can change what is sampled. The handbook therefore gives particular attention to conditioning, composition and preservation of the measurement basis.

Mines, tunnels and subsurface workings

These locations can provide access to fractures and gas, while ventilation, blasting, batteries, corrosion and machinery can create or redistribute hydrogen. Airflow and work activity accompany scientific measurements in the record. Source discrimination and separate certified safety systems are central to interpreting observations from these environments.

Source: Volume I, Chapter 13, Sections 13.1-13.9 and 13.14-13.18.

Climate, access and remote deployment

Cold and permafrost conditions

Cold affects batteries, pumps, tubing, warm-up, instrument response and condensation. The handbook considers the complete system at operating temperature, including heated or insulated enclosures and appropriate power arrangements. A stated temperature range for the sensor alone does not establish that the field package will function reliably.

Frozen ground and the seasonally thawed active layer change sampling access and depth. Snow can store, dilute or redirect gas, and thaw can change water movement and biological activity. Comparisons across seasons therefore account for probe depth, ground state, snow cover, soil temperature and associated gases. Short access windows also increase the significance of redundancy, spares and maintenance planning.

Arid and humid environments

Desert work combines heat, dust, sparse access and strong daily atmospheric changes. The handbook discusses protected inlets, filters, thermal management, repeated background observations and the influence of soil moisture. Dust loading can alter pump performance and sampling delay, while a hot vehicle can expose equipment to conditions beyond the outdoor air temperature.

Tropical and humid settings bring rain, condensation, corrosion, biological variability and difficulties with access or positioning under vegetation. Moisture handling is part of the analytical method: removing water can affect the reporting basis and must be accounted for. Maintenance, sample cleanliness and environmental records become particularly important to comparing measurements.

Offshore and coastal work

Marine applications include dissolved gas, seabed sediments, seeps, pore water and drilling or production streams. Pressure changes, gas loss during recovery, salinity, corrosion and vessel conditions affect the sample. The handbook describes pressure-aware collection, controlled transfer and shipboard or laboratory analysis, with positioning and sample history retained.

Remote stations and logistical limits

An unattended station depends on power, weather protection, sample flow, calibration access, communications and local data storage. Operational status helps explain apparent gas changes and gaps. A remote alert is useful only if the system can distinguish a gas event from a blocked inlet, power failure or other equipment problem.

Across these environments, field performance is understood in terms of actual conditions and maintenance access. Access routes, recovery arrangements, communications and crew capability influence the amount and quality of data collected. These considerations run alongside geological interpretation rather than being treated solely as administrative support.

Source: Volume I, Sections 10.13-10.17, 12.12 and 13.10-13.16; Volume II, Sections 6A.3, 6A.6 and 6A.8.5.

Emerging technologies and conclusions

A progression toward sustained observation

The outlook describes a shift from occasional measurements toward longer-duration, distributed monitoring. Low-power sensors, better sample interfaces, miniature analytical systems, telemetry and automated diagnostics could broaden coverage and reduce the time between observation and interpretation. The handbook separates commercial, pilot-ready, research-stage and speculative capabilities.

New sensors, miniature analysis and fibre systems

Palladium-based materials, organic and printed sensors, miniature pumps and micro-GC systems offer possible improvements in size, power, response or local analysis. The remaining questions include selectivity in mixed gases, drift, manufacturing consistency, humidity, contamination and long-term field durability.

Optical fibre could support multiple sensing points or extended monitoring along boreholes and infrastructure. The handbook distinguishes coatings or nodes intended to respond to hydrogen from distributed acoustic or temperature measurements. The latter can provide flow, fracture or integrity context without directly measuring hydrogen concentration.

Drones, remote sensing and artificial intelligence

Drone sampling with established ground analysis is distinguished from autonomous onboard trace measurement. Rotor airflow, sample position, response delay, wind and payload remain relevant to validation. Satellite and airborne imagery can help map geology, alteration, structure, temperature or associated gases; the handbook treats direct regional hydrogen detection from orbit as speculative for exploration.

Artificial intelligence is discussed for sensor diagnostics, anomaly recognition, integrating datasets and directing additional sampling. The handbook retains measured data, corrections and model outputs separately. Validation across different areas, seasons, instruments and crews addresses whether a model is learning a useful relationship or reproducing biases in its input data.

The handbook's overall conclusions

The two volumes present commercial equipment as one component of a broader exploration method. Geological models define the questions; sampling and instrumentation produce observations; independent confirmation and quality control establish their reliability; and repeated or subsurface measurements examine persistence and significance.

Several conclusions recur: equipment is compared by its actual measurement role; the sampling path forms part of the instrument; concentration ranges require appropriate coverage; composition matters in mixed gases; and scientific analysis remains distinct from safety monitoring. New technology is assessed against these same principles.

Evidence of hydrogen occurrence, an explanation of the geological system and demonstration of sustained recovery remain separate stages of understanding.

Source: Volume I, Chapter 14; Volume II, Sections 6A.8.1 and 6A.8.7-6A.8.10.

APPENDIX / GLOSSARY & SOURCE GUIDE

Source volumes and references

Term	Meaning in this summary
 Anomaly	A result or pattern distinguishable from relevant background using a valid measurement method.
 Appraisal	Investigation of an identified occurrence's subsurface characteristics, persistence and deliverability.
 Composition	The gases present in a sample and their relative amounts.
 Gas chromatography (GC)	Separation of a gas mixture into components before measurement; micro-GC is a compact implementation.
 Matrix	The surrounding gases, moisture or water chemistry in which hydrogen is being measured.
 ppb / ppm	Parts per billion / parts per million: units expressing a small proportion of hydrogen in a sample.
 QA/QC	Quality assurance and quality control: the procedures and checks supporting reliable measurements.
 Redox / Eh	Oxidation-reduction conditions; Eh is a measured potential used to help characterize that chemical environment.
 Selectivity	The ability to distinguish hydrogen from other substances or effects that may influence a reading.
 TCO	Total cost of ownership, including purchase and the costs of operating and supporting equipment.

Where the material appears in the handbook

Topic	Primary source sections
 Geological context and units	Volume I, Chapters 1-2.
 Field measurement methods	Volume I, Chapters 3-7.
 Equipment and packages	Volume I, Chapters 8-10; Volume II, Sections 6A.3-6A.7.
 Survey design and quality	Volume I, Chapters 11-12.
 Environments and outlook	Volume I, Chapters 13-14.
 Manufacturer evidence	Volume II, Section 6A.2, Reviews 1-50; comparative conclusions in Section 6A.8.

Source volumes: Natural Hydrogen Equipment Handbook, First Edition drafts.

Volume I: exploration principles, field methods and equipment selection.

Volume II: Commercial Equipment Reference Manual.

Original Volumes I and II: <https://chapeng.ab.ca/h2handbook.html>

The manufacturer examples illustrate the reviewed categories; the full set contains 50 reviews. Specifications, planning costs and technology-readiness judgments are reported as handbook content.