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GEO-HEAT CENTER Quarterly Bulletin

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SPAS AND BALNEOLOGY

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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

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(Edit. Thill, S. A., Bruxells)

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Computer-generated image of the new spa in 2002. (Bath Spa Project)

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GEO-HEAT CENTER'S 25TH ANNIVERSARY

The Geo-Heat Center and the Quarterly Bulletin celebrate 25 years of continuous operation this year. Much of what we have accomplished over the years was documented in Vol.16, No. 4 (October 1995) and Vol. 14, No. 3 (December 1992). Our beginning can be traced to an international conference held on geothermal energy on the Oregon Institute of Technology (OIT) campus in October of 1974. The Geo-Heat Utilization Center was then established in early 1975 as the publisher of the proceedings from this conference. The 25th anniversary of this conference was commemorated with a second international conference: "International Geothermal Day - Oregon 1999" held on campus and attended by over 100 persons from 30 countries (see Vol. 20, No. 4 - December 1999).

A total of 77 issues of the Quarterly Bulletin have been published starting with Vol. 1, No. 1 in May of 1975. These issues, with an emphasis of the direct utilization of geothermal energy, include approximately 350 articles written by geothermal experts from all over the world. The first issue consisted of 6 pages on heavy yellow bond paper, while current issues vary from 24 to 36 pages, often with a color cover. Issues from Vol. 16, No. 4 (October 1995) to present are available on our website: www.oit.edu/~geoheat/bullet.htm. Other issues can be mailed upon request. More recently, a quarterly newsletter for geothermal heat pump designers and installers, "Outside the Loop" has been developed by the Center in cooperation with the GeoCool Lab at the University of Alabama (editors Steven Kavanaugh and Kevin Rafferty). All of the eight-page issues to the current one, Vol. 3, No. 2 (Summer 2000), are also available on our website: www.oit.edu/~geoheat/otl/index.htm.

The Geo-Heat Center provides free technical assistance (preliminary engineering and economic analysis), applied research, resource information, publications and a 6,000-volume library. Some of the impressive statistics associated with the Center are: the current website has over 2,000 files with 100,000 hits; 12,000 users and 5,000 downloaded papers per month. We now respond to approximately 1,000 technical assistance requests per year. During the past 25 years, approximately 12,000 publications have been disseminated, and staff members have made 200 oral presentations, published 300 papers, completed 50 research projects and provided 150 tours of local geothermal uses to 800 people. Our fundamental reference developed by the Center staff is the 465-page "Geothermal Direct-Use and Engineering Design Guidebook." Funding for most of this work has been provided by the U.S. Department of Energy, Office of Geothermal Technology (now the Office of Geothermal and Wind Technologies).

This issue of the Quarterly Bulletin is devoted entirely to one of the oldest and most basic uses of geothermal energy: spa heating and balneology. In addition to the more famous spas at Bath, England; Spa, Belgium and Baden-Baden, Germany, the editor has tried to select representative samples of geothermal spas from all over the world. It is impossible to present all countries, as we are aware of over 60 that have geothermal spas, including ones in South America and Africa. Additional information on world spas can be found on the official web site of the International Spa Association. ISPA is recognized worldwide as the professional association and voice of the spa industry, representing more than 1,400 wellness facilities and providers from 48 countries. Their website is: http://experienceispa.com. Spa training and international spa tours are organized by Professor Jonathan Paul de Vierville, Ph.D. of the Alamo Plaza Spa at the Menger Hotel in San Antonio, TX. Training and tours for 2001 will be at Karlsbad, Czech Republic (May) and Germany Bad Sulza (July). Information of these activities can be found at: www.alamoplazaspa.com/training/.

Other spa websites include: the World Spa Directory at: www.spamagazine.com, Soak.Net for U.S. natural hot spring resources at: www.soak.net, Aqua Thermal Access for definitive guides to U.S. southwest and northwest hot springs and pools at: www.hotpools.com, and for The Hot Springs Gazette at: www.hotspringsgazette.com

Finally, the editors would like to thank all the authors who have contributed material over the past years, and we would like to continue soliciting articles that publicize the uses of geothermal energy worldwide. Feedback, both pros and cons, on the content and style of the Quarterly Bulletin are always appreciated.

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"TAKING THE WATERS" INTRODUCTION TO BALNEOLOGY

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BACKGROUND

People have used geothermal water and mineral waters for bathing and their health for many thousand of years. Balneology, the practice of using natural mineral water for the treatment and cure of disease, also has a long history. Based on archeological finds in Asia, mineral water has been used for bathing since the Bronze Age, about 5000 years ago. Many hot springs have been used in connection with religious rites in Egypt and by the Jews of the Middle East. The Greeks, Turks and Romans were famous for their spa development and use from Persia to England. The word "spa" traces its origin to a town near Liège in southern Belgium near the German border. Here a spring of iron-bearing water was used by an iron master in 1326 to cure his ailments. He founded a health resort at the spring called Espa (meaning fountain in the Walloon language). Espa became so popular that the word know in English as spa became the common designation for similar health resorts around the world (Lund, 1996).

Great spas have a long history, often stretching back to Roman times. Bath in England, for instance, was originally known as Aquae Sulis, Baden-Baden in Germany as Aquae Aureliae, and Aix-les-Bains in France as Aquae Allobrogum (Rockel, 1986).

Today, especially in Europe and Japan, the use of medically supervised spas has long been accepted. They are used for both treatment and preventive therapy. The former Soviet Union had 3500 spas and some 5000 reconditioning centers all administered and run by the state. In the former Czechoslovakia, there are 52 mineral water health spas and more than 1900 mineral springs, which every year about 220,000 citizens are granted free spa treatment for three weeks, paid by the national health insurance program. The more famous ones are Karlbad in the present Czech Republic and Pieštany in Slovakia. Many of these spas are being privatized today, and are dependent on income from visits by persons from outside the country. In Rotorua, New Zealand, the Queen Elizabeth Hospital used various mineral waters and hot springs muds to help soldiers from the WWII Pacific wars recuperate from battle injuries. In Japan there are over 2500 spas that are used by over 150 million visitors every years. Some of these international uses have been documented by Hotta and Ishiguaro (undated), Lund (1992 and 1996,) in "Stories form a Heated Earth" (1999), and the Geo-Heat Center Quarterly Bulletin (1993).

The Indians of the Americas considered hot springs as sacred places and believed in the healing powers of the heat and mineral waters. Montezuma, the great Aztec leader, spent time at a spa, Aqua Hedionda, to recuperate from his strenuous duties; which was later developed into a fashionable spa by the Spaniards (Salgado-Pareja, 1988). Every major hot spring in the U.S. has some record of use by the Indians, some for over 10,000 years. These springs were also known as neutral ground, to which warriors could travel and rest unmolested by other tribes. Here they would recuperate from battle. Today, there are approximately 210 spas in the USA with 4.5 million persons attending a spa in 1997. Details on the U.S. use of mineral waters and hot springs can be found in Part 2: Balneological Use of Thermal Waters in the USA in this publications.

Improving your health and your appearance, and getting away from stresses to refresh and revitalize your body and your mind are the main reasons why people go to spas and why spas are becoming an increasingly important part of American life. The 7-day miracle, as some refer to a week's spa vacation, provides you with a necessary interlude to change your pace of life and your way of being, to lose weight, shape up, reduce stress, gain confidence, reassess your goals, recharge your vitality, learn new exercise and nutrition behaviors, reward yourself with time out for yourself--and have a good time, a carefree holiday (Van Itallie and Hadley, 1988)

WHAT IS A SPA?

The word "spa" is also used as a Latin abbreviation for: S = salud, P = per, A = aqua, or "Health through Water." In Germany, they refer to the "Kur", which does not mean just a cure, but instead is a series of treatments over time including baths, taking (drinking) water, massage, exercise, mud baths, etc.

For the sophisticated European of the nineteenth century, a spa was much more than just a health resort. The famous spas of France, Germany and Britain were elegant social and cultural centers. Most who took the cure ["kur"] did not do so primarily for medical reasons, but to see and be seen by high society (Rockel, 1986).

Other definitions include (DeVierville, 1998):

"The spa is the social aspect of using water therapeutically."

"The spa is a natural space and place with a perspective on time."

"A spa is a space with a purpose, through a plan, by a purpose, for a period of time."

Spas today can have many forms and emphasize certain treatments. Sarnoff, (1989) classified American spas as follows:

1. Intensive fitness spas - where fitness buffs can trim and tone "to the max" in minimum time.
2. Rejuvenation spas - where you can take advantage of the latest beauty treatments for a younger-looking you.
3. Weight-loss spas - where you can vacation and shed those unwanted pounds at the same time.
4. Athletic camps - where excellent sports programs and exercise classes can be had at a very affordable price.
5. Mineral springs or "magic mud" resorts - where health-giving waters and the oldest, most aristocratic spa traditions await you.
6. New Age retreats - where you can renew your psychic and spiritual self as well as physical well-being.
7. Gustatory hideaways - where you can enjoy and learn about the best in healthful, nonfattening, gourmet fare.

Thus, in summary the purpose of a spa is to provide (DeVierville, 1998):

1. Water (therapeutic through heat and minerals, including muds)
2. Movement (exercise, massage and fitness)
3. Herbal (medical benefits)
4. Dietary (proper food and drink)
5. Life style pattern.

And a spa, to be successful, must have (DeVierville, 1998):

1. Hygiene (cleanliness)
2. Service
3. A unique attractions, such as scenery, special water, special mud, special cure, special food, unique location, unique facility, etc.

PLANNING AND DEVELOPING A SPA (DeVierville, 1998)

A spa plan must have the following for a successful development:

1. Vision
2. Mission
3. Goals
4. Objectives
5. Strategies (how to accomplish the plan)

The categories and dimensions that are part of a spa and should, for the most, be incorporated into its development are:

1. Natural, environmental, ecological
2 Medical, psychological, therapeutic
3. Scientific, technical, research
4. Economical, financial, managerial
5. Planning, architectural, building
6. Social, fashionable, gastronomical
7. Artful, historical, literal
8. Spiritual, mystical, religious

Finally, the items necessary for a spa are:

1. Water
2. Food or nutrition
3. Exercise or movement
4. Massage or body work
5. Mind-body -- physiological
6. Natural therapeutic agents (muds)
7. Environment - area, climate
8. Cultural aspects
9. Management and staff (marketing)
10. Life style patterns or rhythms (time).

WATER AND MUDS

A spa originates at a location mainly due to the water from a spring or well. The water, with certain mineral constituents and often warm gives the spa meaning from one or more of the following points of view (DeVierville, 1998):

1. Religious, mythical, symbolic
2. Social, political, economic
3. Aesthetic, artistic, literary
4. Philosophical, scientific, technological and medical.

Associated with most spas are the used of muds (peloids) which either are found at the site or are imported from special locations. As an example, at Piešťany in Slovakia, there is a special laboratory that test muds or clays for their mineral content and their therapeutic benefits. The muds are stored in tanks and "cured" for maximum benefit. The three classification of muds are:

1. Pure mineral (fango, mud) - neutral
2. Mainly mineral (sea mud or liman) - alkaline
3. Mainly vegetable peloid (moor, peat) - acid

The spas at Calstoga, California, use a mixture of volcanic ash and peat moss for their "muds" (Lund, 1979).

The skin effects of mud are:

1. Increase the body temperature
2. Lowering of blood pressure
3. Influence on mineral metabolism and blood chemistry

Even though hot mud packs have been touted for many aliments, the recommended uses for local treatment are (DeVierville, 1998):

1. Chronic arthritis
- Fibrositis

3. Neuritis, sciatic syndrome
4. After treatment of fractures
5. Sport and industrial injuries.

TYPICAL SPA DESIGN

There are many types of designs for spas, depending upon the local culture, the unique character of the location, and what the developer is trying to achieve in terms of atmosphere, service and type of clientele. Two basic types, with an emphasis on the use of geothermal water will be presented here. The first (Fig. 1) is one originally proposed for Hawaii (Woodruff and Takahashi, 1990) and is similar to ones in Calistoga, California. This design which includes living quarters surrounding the various bathing and soaking pool, lends itself to feature native plants and material in the landscaping and construction. Also, food and drink can be provided, along with small shops and a fitness room for a health and fitness program. The enclosed pool area would provide privacy, but also allow easy access to and from the living area.

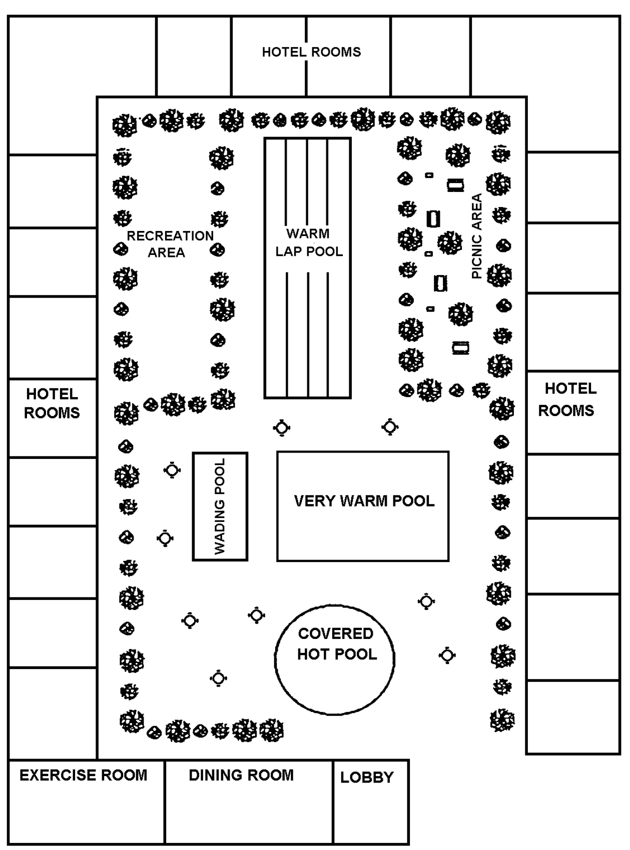

Figure. 1. ***General scheme of a modern geothermal spa located in California (Woodruff and Takahashi, 1990).***

The second design (Figure 2) was also proposed for Hawaii (Woodruff and Takahashi, 1999). This design emphasizes private, semi-private and public bathing and soaking facilities. This is also typical of the design for the Polynesian Pools in Rotorua, New Zealand. This design does not include living quarters, but these could be added at a separate location and could be individual cottages. The semi-private and private pools could then be used by a single family and rented on a hourly basis. This would also be appropriate in cultures were bathing in public is less accepted.

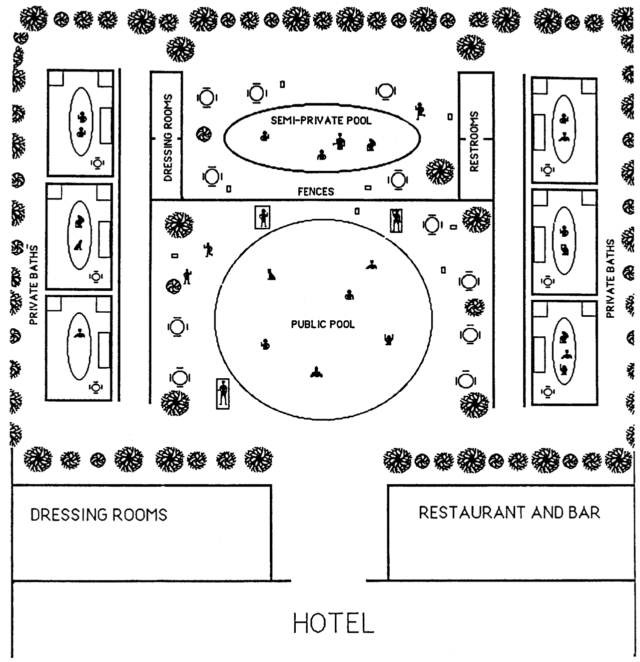

Figure 2. ***Design for a geothermal spa offering private, semi-private, and public bathing facilities (Woodruff and Takahashi, 1990).***

Both of the above designs could be uncovered, completely enclosed or each individual pool covered with a temporary roof for use in inclement weather. Uncovered pools are extremely popular in the evening under a star-lite sky.

TWENTY-FIVE REASONS TO GO TO A SPA

1. To live up to your potential both physically and mentally,
2. To minimize the effects of aging,
3. To establish new eating habits,
4. To feel healthier,
5. To feel happier,
6. To tone up,
7. To reduce weight,
8. To quit smoking,
9. To quit drinking,
10. To look more attractive,
11. To increase athletic skills,
12. To prevent diseases,
13. To help cure common ailments,
14. To treat specific male or female problems,
15. To stretch your body,
16. To stretch your mind,
17. To eliminate or reduce stress,
18. To have fun,
19. To meet people ("plug in" socially),

20. To achieve a better body and more balanced personality,
21. To be pampered,
22. For family togetherness,
23. For individual activity,
24. For solitude, and
25. For relaxation.

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DESIGN CONSIDERATIONS FOR POOLS AND SPAS (NATATORIUMS)

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SWIMMING POOLS

According to ASHRAE (1999a), the desirable temperature for swimming pools is 27°C, however, this will vary from culture to culture by as much as 5°C. If the geothermal water is higher in temperature, then some sort of mixing or cooling by aeration or in a holding pond is required to lower the temperature. If the geothermal water is used directly in the pool, then a flow through process is necessary to replace the "used" water on a regular basis. In many cases, the pool water must be treated with chlorine, thus it is more economical to use a closed loop for the treated water and have the geothermal water provide heat through a heat exchanger. The water heating system in this case, is installed on the return line to the pool. Acceptable circulation rates vary from six to eight hours for a complete change of water. Heat exchangers must be designed to resist the corrosive effects of the chlorine in the pool water and scaling or corrosion from the geothermal water. This often requires, in the case of plate heat exchangers, using titanium plates.

Sizing of the system for temperature and flow rates depends on four considerations (ASHRAE, 1999a), which are also discussed in more detail in achapter on Aquaculture Design by Rafferty (1998). These are:

1. Conduction through the pool walls,
2. Convection from the pool surface,
3. Radiation from the pool surface, and
4. Evaporation from the pool surface.

Of these, conduction is generally the least significant unless the pool is above ground or in contact with cold groundwater. Convection losses depend on the temperature difference between the pool water and the surrounding air, and the wind speed. This is substantially reduced for indoor pools and ones with wind breaks. Radiation losses are greater at night, again especially for outdoor pools, however during the daytime there will be solar gains which may offset each other. A floating pool cover can reduce both radiation and evaporation losses. Evaporation losses constitute the greatest heat loss from pools--50 to 60% in most cases (ASHRAE, 1999a). The rate at which evaporation occurs is a function of air velocity and pressure difference between the pool water and the water vapor in the air (vapor pressure difference). As the temperature of the pool water is increased or the relative humidity of the air is decreased, evaporation rate increases. An enclosure can reduce this loss substantially, and a floating pool cover can practically eliminate the loss. Swimming and other pool uses causing waves and splashing will increase the surface area and thus the evaporation rate.

The required geothermal heating output q_t can be determined by the following two equations (ASHRAE, 1999a):

$$q_1 = \;?\; c_p \, V \, (t_f - t_i)/? \qquad [1]$$

where

q_1	= pool heat-up rate, kJ/h	
?	= density of water = 1,000 kg/m^3	
c_p	= specific heat of water = 4.184 kJ/kg °C	
V	= pool volume, m^3	
t_f	= desired temperature (usually 27°C)	
t_i	= initial temperature of pool, °C	
?	= pool heat-up time (usually 24 hours)	

and

$$q_2 = U \, A \, (t_p - t_a) \qquad [2]$$

where

q_2	=	heat loss from pool surface, kJ/h
U	=	surface heat transfer coefficient = 214.4 kJ/(h m^2 °C)
A	=	pool surface area, m^2
t_p	=	pool temperature, °C
t_a	=	ambient temperature, °C

then

$$q_t = q_1 + q_2 \qquad [3]$$

If there is no heat-up time, which is typical for geothermal pools, then equation [1] will be zero and only equation [2] will apply. Heat loss equation [2] assume a wind velocity of 5 to 8 km/h. For sheltered pools, and average wind velocity of less than 5 km/h, the second equation (q_2) can be reduced to 75%. For wind velocity of 8 km/h, multiply by 1.25; and for wind velocity of 16 km/h, multiply by 2.0 (ASHRAE, 1999a).

SPAS (NATATORIUMS)

Spas or natatoriums require year-round humidity levels between 40 and 60% for comfort, energy consumption, and building protection (ASHRAE, 1999b). Any design must consider all of the following variables: humidity control, ventilation requirements for air quality (outdoor and exhaust air), air distribution, duct design, pool water chemistry, and evaporation rates.

According to ASHRAE (1999b):

> "Humans are very sensitive to relative humidity. Fluctuations in relative humidity outside the 40 to 60% range can increase levels of bacteria, viruses, fungi and other factors that reduce air quality. For swimmers, 50 to 60% relative humidity is most comfortable. High relative humidity levels are destructive to building components. Mold and mildew can attack wall, floor, and ceiling coverings; and condensation can degrade many building materials. In the worst case, the roof could collapse due to corrosion from water condensing on the structure."

Heat loads for a spa include building heat gains and losses from outdoor air, lighting, walls, roof, and glass, with internal latent heat loads coming generally from people and evaporation. The evaporation loads are large compared to other factors and are dependent on the pool characteristics such as the surface area of the pool, wet decks, water temperature and the activity level in the pool.

The evaporation rate (w_p in kg/s) can be estimated for pools of normal activity levels, allowing for splashing and a limited area of wetted deck (Smith, et al., 1993) (ASHRAE, 1995).

$$w_p = A\,(p_w - p_a)\,(0.089 + 0.0782\,V) / Y \qquad [4]$$

where

A	=	area of pool surface, m^2
p_w	=	saturation vapor pressure taken at surface water temperature, kPa
p_a	=	saturation pressure at room air dew point, kPa
V	=	air velocity over water surface, m/s
Y	=	latent heat required to change water to vapor at surface water temperature, kJ/kg

For Y values of about 2330 kJ/kg and V value of 0.10 m/s, and multiplying by an activity factor Fa to alter the estimate of evaporation rate based on the level of activity supported, equation [4] can be reduced to:

$$w_p = 4.16 \times 10^{-5} \times A\,(p_w - p_a)\,F_a \qquad [5]$$

If p_w and p_a are given in bar absolute, then equation [5] becomes:

$$w_p = 4.16 \times 10^{-3} \times A\,(p_w - p_a)\,F_a \qquad [6]$$

And, if w_p is given in kg/hr, then equation [6] becomes;

$$w_p = 15.0 \times A\,(p_w - p_a)\,F_a \qquad [7]$$

Table 1. Common Values for p_w

For p_w:
- at 15ºC water, p_w = 0.0170 bar (1.70 kPa)
- at 20ºC water, p_w = 0.0234 bar (2.34 kPa)
- at 25ºC water, p_w = 0.0317 bar (3.17 kPa)
- at 30ºC water, p_w = 0.0425 bar (4.25 kPa)
- at 35ºC water, p_w = 0.0563 bar (5.63 kPa)
- at 40ºC water, p_w = 0.0738 bar (7.38 kPa)

For outdoor locations with a design dry bulb air temperature below 0ºC, p_a can be taken as 0.0061 bar (0.61 kPa). For indoor locations with a design from 40 and 60% humidity, the following values of p_a can be use:

Table 2. Common Values for pa

Temperature ºC	40% relative humidity bar (kPa)	50% relative humidity bar (kPa)	60% relative humidity bar (kPa)
20	0.0094 (0.94)	0.0117 (1.17)	0.0140 (1.40)
25	0.0127 (1.27)	0.0158 (1.58)	0.0190 (1.90)
30	0.0170 (1.70)	0.0212 (2.12)	0.0255 (2.55)

The following activity factors should be applied to the area of specific features, and not to the entire wetted area (ASHRAE, 1999b):

Type of Pool	Typical Activity Factor (F_a)
Residential pool	0.5
Condominium	0.65
Therapy	0.65
Hotel	0.8
Public, schools	1.0
Whirlpools, spas	1.0
Wavepools, water slides	1.5 (minimum)

It is important to apply the correct activity factor for the estimation of the water evaporation rate, as for example, the difference in peak evaporation rates between private pools (residential) and active public pools of the same size may be more than 100%.

ASHRAE (1999b) recommends operating temperatures and relative humidity conditions for design, and suggests that higher operating temperatures are preferred by the elderly. Air temperatures in public and institutional pools should be maintained 1 to 2ºC above the water temperatures (but not above the comfort threshold of 30ºC) to reduce the evaporation rate and avoid chill effects on swimmers. The maximum water temperature that can be tolerated by the human body (for short periods of time) is 43ºC. The recommendations are as follows:

Table 3. Typical Natatorium Design Conditions

Type of Pool	Air Temperature ^{O}C	Water Temperature ^{O}C	Relative Humidity %
Recreational	24 to 29	24 to 29	50 to 60
Therapeutic	27 to 29	29 to 35	50 to 60
Competition	26 to 29	24 to 28	50 to 60
Diving	27 to 29	27 to 32	50 to 60
Whirlpool/spa	27 to 29	36 to 40	50 to 60

Relative humidities should not be maintained below recommended levels because of the evaporated cooling effect on a person emerging from the pool and because of the increased rate of evaporation from the pool, which increases pool heating requirements. Humidities higher than recommended encourage corrosion and condensation problems as well as occupant discomfort. Air velocities should not exceed 0.13 m/s at a point 2.4 m above the walking deck of the pool (ASHRAE, 1995).

Ventilation is important, especially if chlorine is used to treat the pool water. Ventilation is also used to prevent temperature stratification in areas with high ceilings. Since exhaust air will have chloramine from the chlorine treatment and also have high moisture contents, care must be exercised to vent this air outside and not into changing rooms, toilets and showers. In addition, pool areas should have a light negative pressure and automatic door closers to prevent the contaminated air (laden with moisture and chloramine) from migrating into adjacent areas of the building. ASHRAE (1999b) states that most codes require a minimum of six air changes per hour, except where mechanical cooling is used. With mechanical cooling, the recommended rate is four to six air changes per hour for therapeutic pools.

Natatoriums can be a major energy burden on a facility, thus energy conservation should be considered. This includes evaluating the primary heating and cooling systems, fan motors, backup water heaters (in the case of geothermal energy use) and pumps. Natatoriums with fixed outdoor air ventilation rates without dehumidification generally have seasonally fluctuating space temperature and humidity level. Since these systems usually cannot maintain constant humidity conditions, they may facilitate mold and mildew growth and poor indoor air quality. In addition, varying activity level will also cause the humidity level to vary and thus change the demand on ventilation air.

The minimum air quantity to remove the evaporated water can be calculated from the following expression (ASHRAE, 1995):

$$Q = w_p/[? \ (W_i - W_o)]$$

where:

Q = quantity of air (m^3/s)
? = standard air density = 1.204 kg/m^3
W_i = humidity ratio of pool air at design criteria (kg/kg)(from psychrometric chart)
W_o = humidity ratio of outside air at design criteria (kg/kg)(from psychrometric chart).

The number of air changes per hour (ACH) to remove the quantity of moist air (Q) is:

$$ACH = (V/Q)/3600$$

where:

V = volume of the building in m^3

Normally, the air changes per hour calculated from the above expression is less than the minimum recommended of four to six per hour.

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SPA
"Pearl of the Ardennes"

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from www.spa-info.be
and www.spa.be/fagne/be/en/fagne_b60.html
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The word "spa" traces its origin to a town near Liege in southeast Belgium in the Ardennes near the German border where a spring of chalybeate (iron salts) water is found. Its fame dates from the year 1326 when an iron master of the town of Collin le Loupe, having heard of a fountain in the woods with the health-given properties, went there in hopes of finding a cure for his ailments. His hopes were rewarded; he was cured. To show his gratitude for this miraculous restoration of health, he founded at the spring or fountain as it was called, a health resort which has since become one of the most fashionable watering places in the world. The place was called Espa, which is the old Walloon word for fountain. From that has come the word spa as we know it in English. The original Espa has since become so popular that the word spa is now used to designate all similar health resorts (Swanner, 1988).

Spa is often referred to as the "Pearl of the Ardennes," a town in a wooded valley surrounded by undulating hills and countless rivers and springs. It was also described as "The Cafe of Europe" in the 18th century due to its noteworthy flow of cure-seeking visitors. The history and understanding for the attraction to Spa centers around its springs.

The topography surrounding Spa was initially formed around 500 million years ago. In the 250 million years that followed the imposing mountains began to erode, gradually creating a gentler landscape. The tops of the mountains eroded followed by an accumulation of marine deposits. This in turn was followed by a succession of ice ages, with centuries of melting snow washing away the deposits and accumulated rocks. These rocks became highly de-mineralized and as a result the waters that filter through the region of Spa today contain very few soluble elements. As this clean water filters through the ground, it reappears several hundred meters lower down in a multitude of sparkling springs.

Spa has long been famous for its waters and their therapeutic benefits. The idea of protecting the water started in 1889 with Le Pouhon Pierre-le Grand (Peter the Great Spring) was the first area to be place within a protection zone. At the same time Leopold II of Belgium declared the spring to be of public benefit. The protected area then covered 3,409 hectars. Protection for the main springs was not introduced until 1937. The Spa Monopole company has held the exclusive rights to the Spa waters since 1921 with the mission of developing the economics benefits and providing ecological protection from pollution.

THE SPRINGS AND FOUNTAINS

An ancient description is at the source of the springs, stating:

> "In Tongrie, Gaul country, there is a famous fountain, whence the water, all sparkling with bubbles, has a ferruginous taste, which cannot be experienced until one has finished drinking. This water purifies the body, cures tertian fevers and dispels calculus complaints. The same water, placed over a heat source, becomes cloudy and then turns red."

The origin or the term "pouhon" used to describe the springs, is of Walloon origin defining ferruginous (iron bearing) water springs full of carbon dioxide. Three hundred springs or pouhons gush out in the Spa area where the soil is rich in iron minerals and deeper are carbonate rocks. The acid nature of the water dissolves the iron and reduces the carbonate rock to produce carbon dioxide. The largest and oldest springs have been given individual names. Based on data from Pouhon Marie-Henriette, the temperature of the springs are around 10ºC (50ºF) with the largest cations being iron (21 mg/L), calcium (12 mg/L), sodium (9.6 mg/L) and magnesium (8.0 mg/L). The largest anion is bicarbonate at 135 mg/L. The total dissolved solids are about 200 mg/L and the waters have a pH of 5.15. Carbon dioxide gas is 2,300 mg/L. When the water are used in a spa they are heated to 30 to 34ºC (86 to 93ºF).

Drinking the waters, was known in the olden day as the "Tour of the Fountains." This practice has diminished in importance since the analysis of components of each of the springs. Today the specific properties of each spring has been identified, thus the most suitable cure can be determined. A description of some of the more popular springs is presented below (Connaître Spa, undated).

Le Pouhon Pierre-le-Grand (The Peter the Great Pouhon) is situated in the very heart of the city. The Tsar of Russia visited the city in 1717. He remained at Spa for five week, drinking the waters and taking the "kur"--he thanked this "magical" water which had restored his youth. The spring was decorated around the end of the 19th century with the "Livre d'Or (Visitors Book), a fresco which lists the famous guests who helped give Spa waters their reputation. The Prince of Orange visited the fountain and donated 250,000 florins to construct a new building around the fountain. Built in 1820, it consisted of an adorned building with 18 columns in Tuscan style. It was marked "in the memory of Peter the Great." This building was torn down and rebuilt in 1883 and now has a large open hall attached (Figures 1 and 2).

Figure 1. The Peter the Great Pouhon building (1908).

Figure 2. Interior of Peter the Great Pouhon (1910).

Le Pouhon Marie-Henriette (The Marie-Henriette Pouhon) this water, collected close to the Warfaaz lake, is named in honor of the wife of King Leopold II, who died in spa in 1902. Rich in iron and manganese, a pipe almost 3,000 m (10,000 ft.) long links it to the Spa Thermal Baths establishment.

La Source de la Geronstère (The Spring of Geronstère) is situated closed to the fountain spring road and is well-known since the 16^{th} century. Formerly know as "Enraged", the spring was famous for intoxicating anyone who drank from it, even causing hallucinations! Although this spring water is not very ferruginous or carbonated, its sulphurous scent has been retained intact. Housed under a dome supported by four red marble columns, it is indisputably one of the finest Spa springs.

La Fontaine de la Sauvenière (The Fountain Spring of Sauvenière) is located on the old road linking Spa with Malmédy. In the Middle Ages, this spring was reported to increase fertility! This virtue was associated with Saint Remacle, who himself had the power to purify fountains and make holy springs gush forth! Saint Remacle is said to have left his footprint on a stone there. So, to ensure that newly-weds will produce fine descendants, the young wife had to drink the water at la Sauvenière and, at the same time, place her foot in the Saint's footprint! La Sauvenière remains the oldest of the pouhons. Rich in iron, it has a particularly strong taste.

La Fontaine de Groesbeech (The Fountain Spring of Groesbeeck) is located a few meters from la Sauvenière spring. Less powerful, it nevertheless retains a family "taste". This spring bears the name of Baron de Groesbeeck, who, in 1651 has a small niche built in the wall bearing his coat of arms. This fountain spring is also called "pécquet" because, like juniper, it has diuretic (tending to increase the flow of urine) properties.

La Source de la Reine (The Queen's Spring) is located inside the Baths. It draws its strength from the Fagne de Malchamps (a large forested park located south of the city). Low in salt and renowned, among other things, for its diuretic and toxin-eliminating effect, the Reine spring is above all know for being bottled under the name of Spa Reine.

Fountains in the Center of Spa. At a time when, unlike today, not all inhabitants had the luxury of running fresh water, the provision of drinkable water was a considerable problem. Water was necessary not only for humans to drink, but also for watering the domestic animals and washing clothes. Since there were not adequate wells, it was not always possible to find drinking water close to the houses. If this was the case, people would frequent the public fountains and pumps where they could have access to clean drinking water. In Spa a number of fountains were available in the downtown area for public use. **La Fontain du Perron** is located in front of the city hall where the water flows into four basins. In 1668, the magistrate of Spa sent a demand to the prince requesting that a fountain be built to serve the needs of visitors and those living in the area. There were severe fines for anyone who polluted the fountain, and it was forbidden to allow animals to drink from the water basin or to wash clothes in them. The fountain was in the form of a pyramid on top of which were three frogs of bronze with water flowing out of their mouths. On top of the frogs was found a pine cone and cross making the entire monument height approximately 5 meters (17 feet). In 1850 the fountain was found to impede traffic and was demolished. It was rebuilt in 1890 with the original frogs and stones used in the construction. **La Fontaine Monumentale** was adorned with two nude children on top and along the sides with children riding a large fish. There was also, in bas-relief, a while marble statue of Queen Marie-Henriette, surrounded by a royal coat of arms. This fountain was established on the location of an old mill. According to the writer, Jean D'Ardenne in 1876, the millrace ran along the street in a stone tunnel and at times one was obliged to walk beneath the tunnel to enter some buildings. The door of the famous hotel Waldeck was nearby and sometimes a visitor would be drenched entering it. It was renovated in 1990 and the water is now furnished by a pump.

La Fontaine des Jardins du Casino. A casino is located in the square opposite the Baths. In the center of the square is a fountain surrounded by benches and flowers, erected in 1925. It was removed in 1947 and reestablished in 1955 (Fig. 3). In 1956 it was adorned with engraved images depicting the fountains of Sauveniére, Géronstère, Baisart and Tonnelet. These engravings were the work of Frans Van Ranst, who moved to Spa in 1946 to head up the Art school and courses in sculpture. He is also the creator of the memorial in honor of the liberation of Spa in 1944 by the U.S. 1st Army.

Figure 3. ***The Fountain of the Gardens of the Casino.***

THE THERMAL SPA

Les Thermes de Spa (The Spa Thermal Baths) was constructed from 1862 to 1868. The building, located in the center of town (Fig. 4) is in the French Renaissance style designed by Léon Suys. The construction cost 1.5 million french franks, an exorbitant amount for the times. The building today remains one of the most beautiful in Spa. The waters here are naturally iron rich and carbonated. The thermal waters are currently used for the carbonated baths to treat cardio-vascular ailments. The jetted waters are used to help rheumatoid arthritis. Sulphur inhalations are used to help respiratory problems and anemia. The water in this bath comes from the Marie-Henriette spring (Figure 5) and is heated to 33.8ºC (92.8ºF). Massages, hydrotherapy and exercises are also a part of the provided treatments.

Figure 4. ***The Spa Thermal Bath building.***

Figure 5. ***The Marie-Henriette spring source in the bath.***

Peat baths are also provided where oneself is immersed in a mix of Fagnes peat and carbonated water heated to 40ºC (104ºF). It combines muscular relaxation with treatment for rheumatism and arthritis. Local applications of warm peat - especially on the spring, make excellent poultices.

Showers are synonymous with a stay at the Spa Thermal Baths. By exposing specific parts of the body to high pressure jets of water, certain conditions can be treated. Warm showers for heart stimulation and sweating, cold showers for their toning effect.

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BATH
A WORLD HERITAGE SITE

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In the spring 2001, the naturally occurring thermal springs of Bath southeast of Bristol, England, a World Heritage Site, will be home to a state-of-the-art new Spa, and public bathing will once more be available–for the first time since 1978.

But, this will be a new Spa with a difference–it already has more than 2,000 years of history, and the water in which people will bathe, relax and recuperate fell as rain over 10,000 years ago!

The Bath Spa Project and the revival of the new Spa has been made possible by an £8M (US$ 12M) grant from the Millennium Commission, and a collaboration between: The Local Council in Bath–Bath & North East Somerset, The Bath Spa Trust, and the company selected to manage the operation of the Spa–Thermae Development Company.

HISTORY: BATH THROUGH THE AGES

There is archaeological evidence that occupation based around the hot springs on which the city of Bath is built began at least 8,000 years B.C. Coins thrown by Celts into the water, probably as offerings to their God, Sul were found during excavations of the King's Bath. The legend that Bath was founded by Bladud was first documented by Geoffrey of Monmouth, who published his "History of the Kings of Britain" in 1136.

The story is told that Bladud had returned from his travels a leper. Because of his illness he was confined, but escaped in disguise from his father's court and came to a place called Swainswick where he was employed as a swineherd. In cold weather, he saw his pigs wallowing in a mire. He found that the mud was warm and the pigs enjoyed the heat. Noticing that the pigs which bathed in the mire were free of scurfs an scabs, he reasoned that he might benefit from the waters. Cured of his leprosy, he returned to his father's court where he was restored to his inheritance. He succeeded to the throne on his father's death; whereupon he founded the city of Bath around the hot springs and built the baths so that others might benefit as he had done.

ROMAN

AD 43–The Romans started the development of "Aquae Sulis" as a sanctuary of rest and relaxation, not a garrison like most Roman towns– through the taking of the waters was described by Tacitus in AD 80 as "one of those luxuries that stimulate to vice."

AD 70–The Romans built a reservoir around the hot springs, a sophisticated series of baths, and a temple, dedicated to the goddess Sulis Minerva. As a religious shrine and bathing complex, Aquae Sulis attracted visitors from across Britain and Europe–foreshadowing Bath's status as a tourist attraction. The Romans also used the Cross and Hetling springs.

AD 367–With demise of Roman occupation of Britain, the great baths and temple of Aquae Sulis fell into ruin. They remained hidden until 1790 when foundations were being dug for the Pump Room.

MEDIEVAL

11th Century–The King's Bath was built over the temple precinct and spring, as part of an infirmary.

12th Century–Founding of St. John's Hospital. Henry of Huntington writes: "Where the hot springs...supply the warm baths which stand in the middle of the place, most delightful to see and beneficial to health....infirm people resort to it from all parts of England, for the purpose of washing themselves in these salubrious waters; and persons in health also assemble there, to see the curious bubbling up of the warm springs, and to use the baths."

1449–Barnwell writes: "...a report has reached the ears of the bishop that the heavenly gift of warm and healing waters with which the city of Bath has been endowed from of old is turned into an abuse by the shamelessness of the people of that city."

ELIZABETHAN (1558-1603)

16th Century–The three baths (King's Bath, Cross Bath and Hot Bath) continued to attract visitors who came in search of a cure of various ailments. Interest in the curative properties of spring water helped to revive the economy of Bath after the decline of the cotton trade.

1562–The first medical treatise on Bath's waters awakens renewed interest in the spa.

1574–Elizabeth I's visit draws the nation's elite to Bath.

1576–Queen's Bath built besides the King's Bath.

1661–Installation of the first drinking pump at the King's Bath.

1663–Charles II brought his infertile wife to bathe in the Cross Bath.

1687–The Catholic wife of James II became pregnant soon after bathing in the Cross Bath–ensuring a male Catholic successor and prompting a Protestant uprising.

1692, 1702, 1703–The visits of Queen Anne in the 1690s and 1700s set in motion a period of development in which the city became "the premier resort of frivolity and fashion." Queen Anne visited Bath to take the waters–where royalty led, the aristocracy followed and in time, led to the rebuilding of the city, which in 1668 had a population of just

1200. The subsequent popularity of the baths in the Georgian era resulted in the great rebuilding of the city to produce the 18th Century layout and architecture of today's World Heritage site.

GEORGIAN (1714-1820)

1738–Start of the construction of The Royal Mineral Water Hospital reflected a new period of faith in the healing properties of the waters. It is also notable as the only building on which the three men most responsible for the construction of Georgian Bath–John Wood the Elder, Beau Nash and Ralph Allen–collaborated. While the beneficial and healing properties of the water have always been acknowledged, modesty and decency have not always been inherent in Bath's "spa culture." John Wood the Elder writes at this time: "The Baths were like so many Bear Gardens, and modesty was entirely shut out of them; people of both sexes bathing by day and night naked."

1777–Hot Bath rebuilt to the design of John Wood the Younger.

1783-98–Cross Bath rebuilt and then enlarged.

1788–New Private baths (now demolished) built between King's Bath and Stall Street.

1790s–Great Pump Room built. While excavating the foundations for the new Great Pump Room, many of the first finds relating to the Roman Temple were made.

1798–The publication of "The Comforts of Bath," a satirical view of life in Bath, reflects the infamous lifestyle of elements of Georgian society. The Pump Rooms and the baths were the center of much revelry throughout this period when Bath became known as the "premier resort of frivolity and fashion."

VICTORIAN

1880–King's Bath excavated.

1889–The New Private baths were built over the Roman west baths–treatments included the Schnee Bath which used electricity (the New Private Baths were demolished in the 1970s).

20TH CENTURY

1900s–Bath spa water was bottled and sold as Sulis Water, promising relief from rheumatism, gout, lumbago, sciatica and neuritis.

1920s–Following the First World War, thousands of wounded soldiers rehabilitated in spa towns such as Bath. Construction of the public swimming pool at Beau Street.

1948–Following the establishment of the National Health Service, the health authorities of Bath made arrangements to provide water-cure treatments on prescription.

1970s–Roman Rendezvous–in the 1960s and 1970s, the Great bath was the setting for parties which mirrored the revelry of earlier spa culture.

1976–Withdrawal of NHS funding resulted in the closure of the Spa Medical Facility.

1978–Public health concern lead to the closure of the Beau Street and Cross Baths for bathing; though, the Roman Baths and Pump Room soon became one of the UK's leading tourist attractions.

1980s–Various bids led by commercial consortia to reopen the Spas for bathing failed due to the huge capital cost of restoration.

1983-5--Drilling of boreholes beneath the King's and Cross Springs ensured the supply of clean water.

1997–Successful bid to the Millennium Commission for a lottery grant which would enable Bath & North East Somerset council to reopen the baths and revitalize thousands of years of spa culture.

THE BATH SPA PROJECT

On 13 July 2000, Bath & North East Somerset council voted to commit itself to funding the £19 (US$ 28.5) million Bath Spa Project The decision signaled the end of a 22-year period in which Bath, which was founded and evolved as a City on the basis of its hot thermal springs, existed as a Spa in name only. No one has actually bathed in Bath's natural spa water since 1978, due to a withdrawal of NHS support for the medical spa and uncertainty over the purity of the source.

With the offer of a £7.78 (US$ 11.7) million Millennium Commission grant to support the Project already in place, building of a widely-acclaimed new Spa, designed by Nicholas Grimshaw & Partners, commenced in August 2000.

Various attempts - five in the 1980s and 90s - were made by the local council and by business concerns to reopen the baths, all of which ended in failure as it became clear that the capital cost of restoration was too great to allow profitable operation.

Throughout this period, local opinion has supported all efforts to restore Bath's historic spas and visitors to the city have remained frustrated and puzzled by the lack of Spa bathing facilities. Indeed, an area of the City, rich in culture, architecture and history - just a few hundred yards from the famous Pump Rooms - steadily degenerated.

Control of the hot springs was, in fact, entrusted to the Civic Authority in the Charter of Incorporation of the city of Bath (1590), it being the intention of Queen Elizabeth I that the thermal waters should be accessible to the public in perpetuity.

As the current guardians of the waters the Council's aspirations to make bathing facilities available on reasonable terms to all local residents are consistent with the aims and criteria for applications to the Millennium Commission.

An archaeological exploration of the Beau Street site has already been completed, and the construction programme and refurbishment of five buildings began in August 2000. The reopening of Bath's Millennium Spa is planned for spring 2002.

The Scope of the Bath Spa Project

Cross Bath	The Cross Bath will be restored as a working spa for bathing. Residents will have special access rights.
New Spa Building	The new spa building - a Bath stone cube, in a translucent glass enclosure - will be built on the site of the 1920s Beau Street swimming pool, and will house the main spa complex. From the rooftop pool and terrace bathers will enjoy views across Bath's skyline. Other pools within the spa will be located on different levels. Facilities will include whirlpools, steam room, exercise area, rest areas, treatment rooms and cafe.
Hot (or Old Royal) Bath	The Hot Bath will house the Preventorium, a medical treatment center providing preventative medicines and therapies such as massage, physiotherapy, hydrotherapy and acupuncture.
The Hetling Pump Room	The Hetling Pump Room will house an educational, research and interpretive center plus administrative facilities.
The Bath Spa Thermal Project	The Thermal Resource Project will research, explore and monitor the thermal waters to achieve greater understanding of their sources and ensure their protection for future generations.

THE ENERGY AND WATER SOURCE

Energy and water are available from three separate springs, each tapped by boreholes, and located quite close to the new development. These three sources are known as the Kings Spring, the Hetling Spring and the Cross Bath Spring. Each of these springs now have boreholes sunk to varying depths, to intercept the water at a lower level. All three sources were developed and used by the Roman inhabitants, but it is the Kings Spring which has been studied in most detail. Past estimates have indicated that the thermal output from the springs varied between 8 l/s and 27 l/s (127 and 428 gpm), and that the temperatures ranged from 40ºC to 49ºC (104 to 120ºF). Much work was carried out during the 1980s to establish a number of new boreholes, and these sources will now be used to serve the new Bath Spa development. During this period there was extensive monitoring of the sources, which also considered the effect on these sources of extraction through new boreholes located elsewhere in the city. This research has formed the basis of the energy capacity used in analyzing the various systems options considered for serving the new development.

The Kings Spring

The Kings Spring is located under the existing Pump Rooms and rises naturally into the Kings Bath, at the center of the Roman Bath's Museum. The supply for the Bath Spa Project is brought to the surface through an inclined borehole, with its head located in the adjacent Stall Street. The borehole extends to a depth of some 76 m (250 ft) below the Stall Street datum, and the capacity of this source is limited to 0.50 l/s (8 gpm) at an average temperature of 43ºC (104ºF) and represents an energy source of approximately 65 kW. This source is located approximately 100 m (330 ft) away from the new main building, and will be connected to the new systems through new pipework.

The Hetling Spring

The Hetling Spring is located in front of the existing Hot Bath, in Hot Bath Street. This has the lowest output of the three springs, rated at approximately 0.42 l/s (6.6 gpm). This spring has potentially the highest temperature, yielding around 45ºC (113ºF). It is estimated that 50 kW of useful heat can be derived from this source.

The Cross Bath Spring

This is visibly the most interesting, in that the borehole termination appears above the surface of the exiting Cross Bath pool. The existing top of the borehole will be reconfigured to take the water into the new Beau Street plant area, but will maintain its presence in the redeveloped Cross Bath. The spring yields up to 2.39 l/s (38 gpm) at a temperature around 44ºC (111ºF). This gives the greatest capacity of up to 300 kW.

The Composition of the Springs

It is not only energy which is important to the development, but also the chemical composition. Again during the 1980s much investigation work was carried out on the chemical compositions, and these are summarized in the table below.

Summary of Water Analyses (from Kellaway, G. A. 1991)

Paramenter (mg/l)	Stall Stree Borehole	Hetling Spring	Cross Bath Spring
Sodium	187	195	183
Calcium	390	358	380
Sulphate	1010	1015	1050
Chloride	286	340	288
Bicarbonate	199	193	189
Magnesium	53	57	54
Silicon	21	21	–
Iron	1	0.5	02.

The analyses show that the thermal waters all contain sodium, chloride and sulphate ions in high concentrations. In addition, the iron content of the Kings Spring has the potential for staining, and it is this source which also has high suspended solid levels.

Since 1978, the hot spring spa pools at Bath have been closed following the identification of a free living pathogenic amoebae in the water. In order to establish safe supplies of the thermal water, lined boreholes were drilled into the Kings and Cross springs in the 1980's to abstract water from a depth and temperature at which the amobae can not exist. However, as part of the new develop-ment it is still necessary to provide treatment to the three pro-posed sources prior to their use in the new Bath Spa complex.

Building Systems and the Use of the Water

Original design development culminated in the release of an energy report which was issued in July 1998 as part of the initial scheme design. This report was based on an architectural scheme and building layout which has subsequently undergone various changes. The energy system at that time had been based on the principle that the spring water was initially passed through the pools to heat them and maintain the pools temperatures at 33.0ºC (91ºF). The water from the pools was then passed through a number of heat exchangers where the heat was extracted through a series of heat pumps to serve the heating load of the building.

This solution raised a number of concerns, mainly that there would be relatively high costs associated with treating all the available spring water required to maintain the heat balance in the pools. Following further design work, a flexible system was developed which allowed heat to be extracted from the spring water without the water being circulated through the pools. This ensured that the maximum heat capacity could be derived from the thermal water sources, without the need to treat large amounts of spring water. The option to take the water directly to the pools, through the water treatment system was maintained.

Design Criteria

The building has a wide range of uses, and therefore internal design conditions vary. However, the main areas within the pools and associated areas require internal temperatures of 29ºC (84ºF). The external design dry bulb temperature was set at –6ºC (21ºF), although the development is located in the center of the City of Bath, and is normally subjected to local temperature effects.

Building Loads

Building loads are incurred by heat losses from the building, due to fabric and infiltration losses, the need for hot water for showering and washing, and the requirement for maintaining the pools at the correct temperature. The overall building design heat load is approximately 620 kW at peak design condition. The pools require 300 kW to maintain a design condition of 33ºC, and this in fact can be met extracting heat from the spring water, which in total has a capacity approaching 415 kW. However, the spring water alone cannot meet the whole building demand, and therefore supplementary energy systems are required. The building also requires fresh air to be provided to most parts of the buildings, and where possible these systems use heat reclaim in the form of run around coils.

System Design Options

Following discussions with the operator and Client, it was decided to investigate in detail the system options which would meet the thermal requirements for the building. However, the total energy consumption of the building is not limited to heating and thermal loads. The electrical consumption for the building also has to be considered. For the new Bath Spa building, the electricity costs will range between 3.7 p/kWh (5.5 ¢/kWh) and 7.0 p/kWh (10.5¢/kWh), depending on the time of year and usage, compared with 0.9 p/kWh (7.4 ¢/kWh) for gas. Also, from April 2001, the UK government intends to introduce a Climate Change Levy, which again will have the greatest impact on electricity costs. With these costs in mind, and taking into account recent experience on similar projects, it was decided to include the use of Combined Heat and Power in the system options, which is also expected to provide a benefit in taxation from 2001.

System Study Conclusion

The original proposals extracted as much energy as possible from the spring water supply. However, to do this heat pumps were used to extract the heat, which in turn use electricity as the primary energy source. Electricity is both relatively expensive, and has a high CO_2 production, when compared to gas as a primary fuel. However, the system does make a complete use of the spring water.

Systems were compared using energy and maintenance costs and CO_2 production. Financially a simple CHP and boiler combination is the best option with potential payback within 2 years and this is because there is no heat pump installation. However it has a higher CO_2 production because it is not making such effective use of the spring water. For limiting CO_2 production, a combination of CHP, heat pump and gas boilers gave a very low level, when compared to the other systems.

The building system design has now been developed to use as much of the spring water directly, and using a CHP and boiler combination. The warm thermal water is used:

- To preheat the incoming mains water, which is needed for showering and washing.
- To provide make up water to the pools to replace water lost be evaporation.
- To directly feed the pools if needed.

This system provides a good balance between costs, CO_2 production and spring water usage. Whilst the development is not wholly reliant on the continuing availability of the spring water, it is central to the day to day operation of the building, providing natural spa water to the pools and making an important contribution to the energy requirement of the building.

BADEN-BADEN
A FAMOUS THERMAL SPA WITH A LONG HISTORY

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INTRODUCTION

One of the most prestigious and historic thermal spas in Germany can be found in the southeastern part of the country. Located at the eastern border of the Upper Rhine Graben (Figure 1), the city is nestled between vineyards, forests and the plains of the Rhine valley; where, the River Oos leaves the mountains of the Black Forest. The hot springs are known at least since Roman times, and the spa was a social center for the European nobility in the 19th century (the "Belle Époque"). Baden-Baden is still considered as a top place for balneological treatment and society events.

Baden-Baden has an elevation of 161 m (528 ft) above sea level (city center); however, the lowest point in the city is 112 m (367 ft) a.s.l. in the Rhine Graben, and the highest 1003 m (3290 ft) a.s.l. on Badener Hoehe in the Black Forest. With this location at the foot of the Black Forest, 61.5 % of the area of the city comprise forest.

Several hot springs supply thermal water to the spa facilities, with temperatures ranging from 52 to 67 EC (130-153 EF) and a mineralization of 2680-3522 mg/kg (ppm). Most of the springs are natural; however, in the 1960s thermal water was also found in two drilled wells. The total thermal water production in Baden-Baden is 9.4 l/s (149 gpm). The water has an energy content of ca. 2 MW (ca. 6.8 million Btu/h), but the energy use is not yet complete.

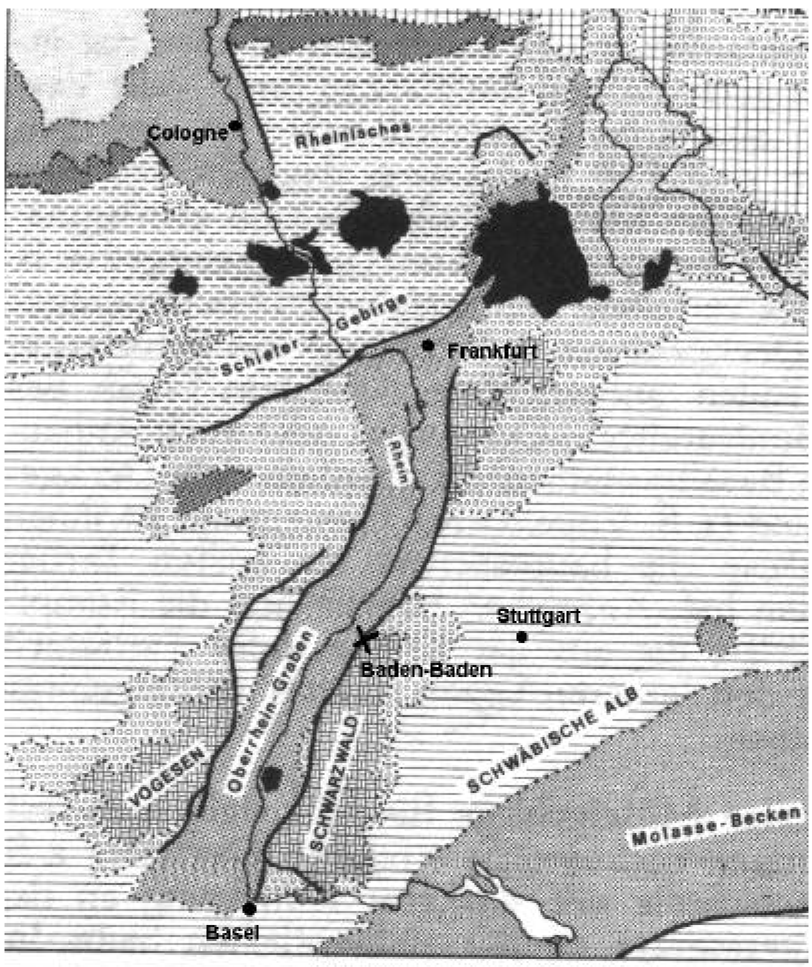


Figure 1. Location of Baden-Baden at the eastern edge of the Upper Rhine Graben (Oberrhein-Graben), map after Henningsen (1976).

HISTORY OF BADEN-BADEN AND THE THERMAL SPRINGS

The earliest traces of human life in the valley of the River Oos date from the stone age, ca. 10,000 years ago. From bronze age, tombs have been found dating ca. 1000 B.C.

Not surprisingly, the Romans made use of the hot springs. The city was founded as “Aquae Aureliae” and their development peaked in the 2nd century A.D. Stately buildings and, of course, the “thermae,” coined the image of the city. People, from many parts of the Roman Empire, came in search for mitigation of their sicknesses, including the Emperor Caracalla. After 260 AD, the German tribe of the Alemans invaded the area, and most of the city was destroyed. The thermal bathing ceased for several centuries. However, traces of this first blossom of thermal bathing in Baden-Baden still exist, e.g. in the ruins of a soldier´s bath around 2000 years old which have been found in 1847 in the main thermal area.

In the 6th century, the Merowingian king Dagobert III gives the area including the hot springs to the Weissenburg monastery. The first castle (Altes Schloss) was built in 1102 as “Hohenbaden” (destroyed by fire in the 16th century; today ruins). Markgräfin Irmengard installs a monastery in 1245. In 1256 in a document of Markgraf (Earl) Rudolf von Baden for the first time the name "Stadt Baden" (Baden city) is used. From 1384 to 1399, the new castle (Neues Schloss) is built (destroyed by fire in 1689; rebuilt, the form seen today was completed in 1847).

The thermal waters become increasingly important. Markgraf Rudolf III offers a part of the thermal baths to his knights in 1306. In the year 1365, the privilege of secure travel is given to Strasburg citizens for visiting the thermal baths of Baden. In the 15th century, the bathing activities flourish. Emperor Friedrich III visits Baden for bathing in 1473. In 1480, the poet Hans Foltz publishes a “Bäderbüchlein” (baths booklet) describing the hot springs. Markgraf Christoph I controls the bathing activities in 1488 by legal orders. In 1507, he gives a city regulation to Baden and introduces a tax on bathing (Kurtaxe). The court doctor, Dr. Johannes Matthäus, starts in 1601 with mud baths (Fango). A book about the springs is published in 1625 by Johann Küffer, mentioning 12 springs; one of the springs, the “Brühequelle,” is used to clean and boil fowl and pig (Küffer, 1625).

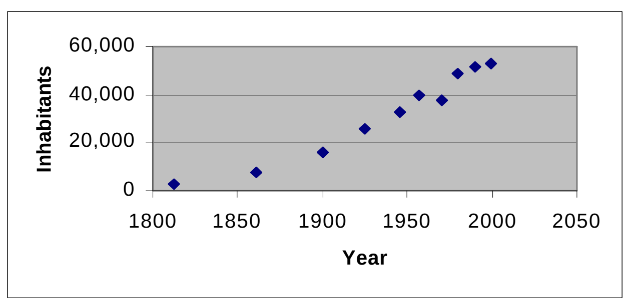
In the year 1688, French troops occupy Baden. On August 24, 1689 a huge fire reduces most of the city and the castles to cinder and ashes. The reconstruction of the city did require almost a century. The fire also destroyed the monastery “Kloster vom Heiligen Grab,” located directly in the thermal area and founded in 1670 by Markgräfin Franziska. In 1698, it is rebuilt; today, it houses a high school.

In the neighbouring city of Rastatt, diplomats and highnesses meet in 1797 at the "Rastatter Kongress." They detect the Baden spa, and a new era with the high society of Europe starts for Baden-Baden. 1804 Queen Luise of Prussia visits Baden-Baden to improve her health. Plans for a new spa area are drafted in 1810. In 1811, the building of the college of Jesuits is converted into a casino. A steam bath is constructed in 1819, and a (thermal water!) drinking hall in 1824. The original balneological building (Kurhaus) dating from 1765 is replaced in 1821-23 by the building which exist today. The large, 90 m long drinking hall with Corinthian columns and frescos is completed in 1842. In 1850, Queen Augusta of Prussia, later to become Empress, stays in Baden-Baden for the first time. Another steam bath (Altes Dampfbad) is constructed in 1846-1848, including a hot spring (“Ursprungsquelle“) delivering roughly 118 m3 (31,200 gallons) of thermal water with almost 60EC (140EF) per day.

In 1858, Otto v. Bismarck and Cavour stay in Baden-Baden, and the first international horse race is conducted near the village of Iffezheim in the neighborhood of Baden-Baden. 1860-62 a theater is built, following the prototype of the Opera in Paris; a (not successful) ambush on King Wilhelm of Prussia happens, and in 1863 three Emperors met in Baden-Baden in the "Hotel d'Angleterre:" Franz Joseph of Austria, Tsar Alexander of Russia and Napoleon III.

From 1863 to 1875, the annales of Baden-Baden name many VIPs of the time: Dostojewski, Madame Viardot, Clara Schumann, Johannes Brahms, Victor Hugo, Richard Wagner, Friedrich Nietzsche, Queen Victoria of England and Prime Minister Disraeli. In 1877, the Friedrichsbad is inaugurated, 1893 the Augustabad. The presence of nobles from all of Europe is documented by the construction of a Romanian orthodox chapel, built by Leo von Klenze in Greek style in 1863-66 (housing the grave of the Romanian Prince Stourdza), and of a Russian church in 1880-82, planned by Belzer in Byzantinian style.

The bathing tradition of Baden-Baden attracts guests also throughout the 20th century. The infrastructure is continuosly improved, with a conference center in 1968, the Caracalla spa in 1985 and the latest addition, a festival hall for 2650 visitors in 1998. The growing thermal spa business fueled the economy and resulted in a steady increase in the Baden-Baden population since the end of the 19th century, as the following graph shows (prepared with data from the official website of Baden-Baden municipality, incl. 1999 values):



By the end of 1999, Baden-Baden had a population of 52,627.

THE HOT SPRINGS

The existence of the hot springs is related to the deep faults at the eastern end of the Upper Rhine Graben. The crystalline rocks of the Black Forest are displaced downwards by almost 2 km (ca. 6500 ft) in the graben, and a number of

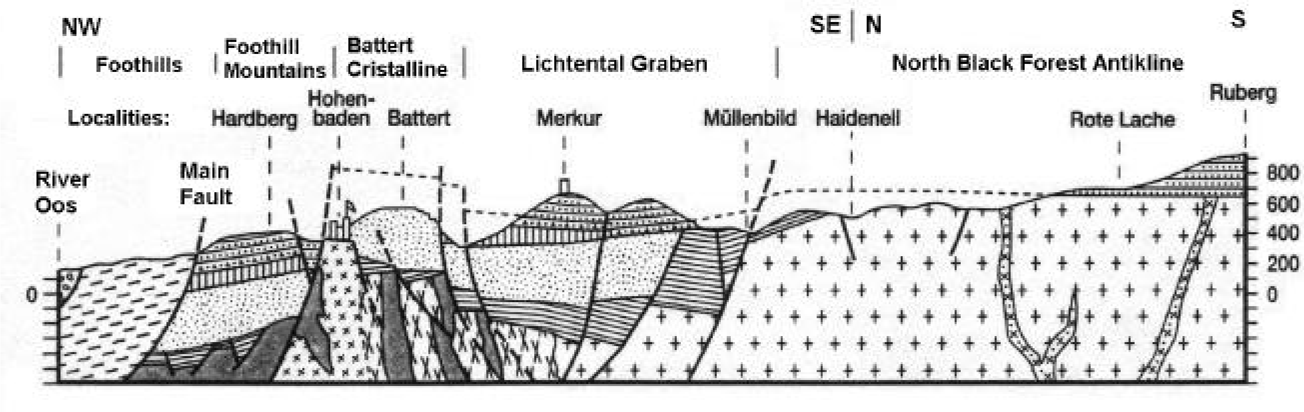


Figure 2. ***Geological profile through the faults at the eastern end of the Upper Rhine Graben in Baden-Baden (from Landesarchiv BW, 1995).***

faults delineate blocks in different elevations (Figure 2). The original springs mostly are located close to the Main Thermal Fault (Figure 5) at the SE-slope of the "Florentiner Berg;" where, the new castle (Neues Schloss) is built upon. The springs exist since diluvial (flooding) times. Since then, sinter layers did built up to about 6 m thickness below the springs. Figure 3 shows the location of the springs in use in the middle of the 19th century.

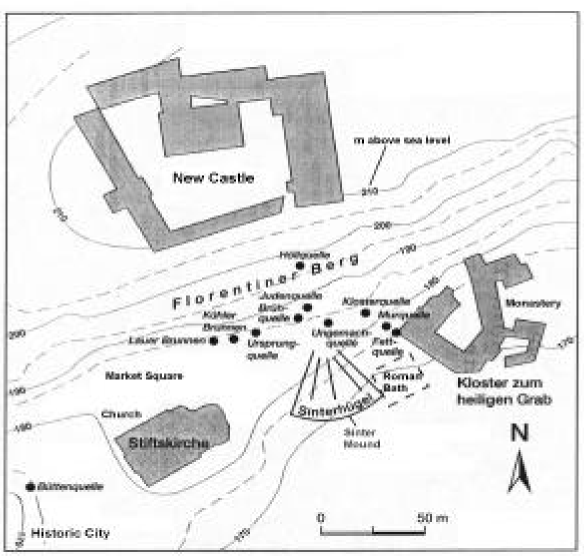


Figure 3. ***The hot springs of Baden-Baden prior to the catchement works in 1868 (from Landesarchiv BW, 1995).***

From 1868 on, a system of tunnels was constructed to catch the springs (Figure 4). The goal was to increase production and temperature. Because of the high temperatures, the work was difficult and took until 1871. The system consist of two main tunnel areas, one just below the castle with the "Friedrichstollen" (stollen = tunnel) as main tunnel, the other close to the Marketplace with the "Kirchenstollen" and "Rosenstollen" The total production could be increased by ca. 20%. A new, large bathing facility was built, the "Friedrichsbad" (completed 1877). To make room for the bath, most of the sinter mound had to be removed, with part of the stones cut and used for special building parts.

Between 1894 and 1897, further addition were done to the tunnel system (mainly the new tunnel capturing the "Neue Stollenquelle"). The tunnel system remains unchanged since then and has an overall length of ca. 200 m (660 ft). The thermal water contains mainly sodium chloride (NaCl); an example of an analysis is listed in Table 1. The genesis of the thermal water is not yet clear. A theory is that the water infiltrates in the Black Forest and is heated while passing through the fractures in the crystalline; contents in lithium and fluoride support this theory. However, the sodium chloride can not be accounted for with the crystalline; fragments of mid Triassic evaporates in the fault area may be the source.

DRILLING FOR THERMAL WATER

Increased need for water for new balneological facilities prompted a search for additional resources of thermal water. Geophysical investigations using geoelectrical and geothermical methods revealed a possible field to the north of the "Florentiner Berg," with a geothermal gradient of 28EC/ 100 m (15EF/100 ft)! In this location, called the "Pflutterloch." two boreholes were drilled in 1965-66. One

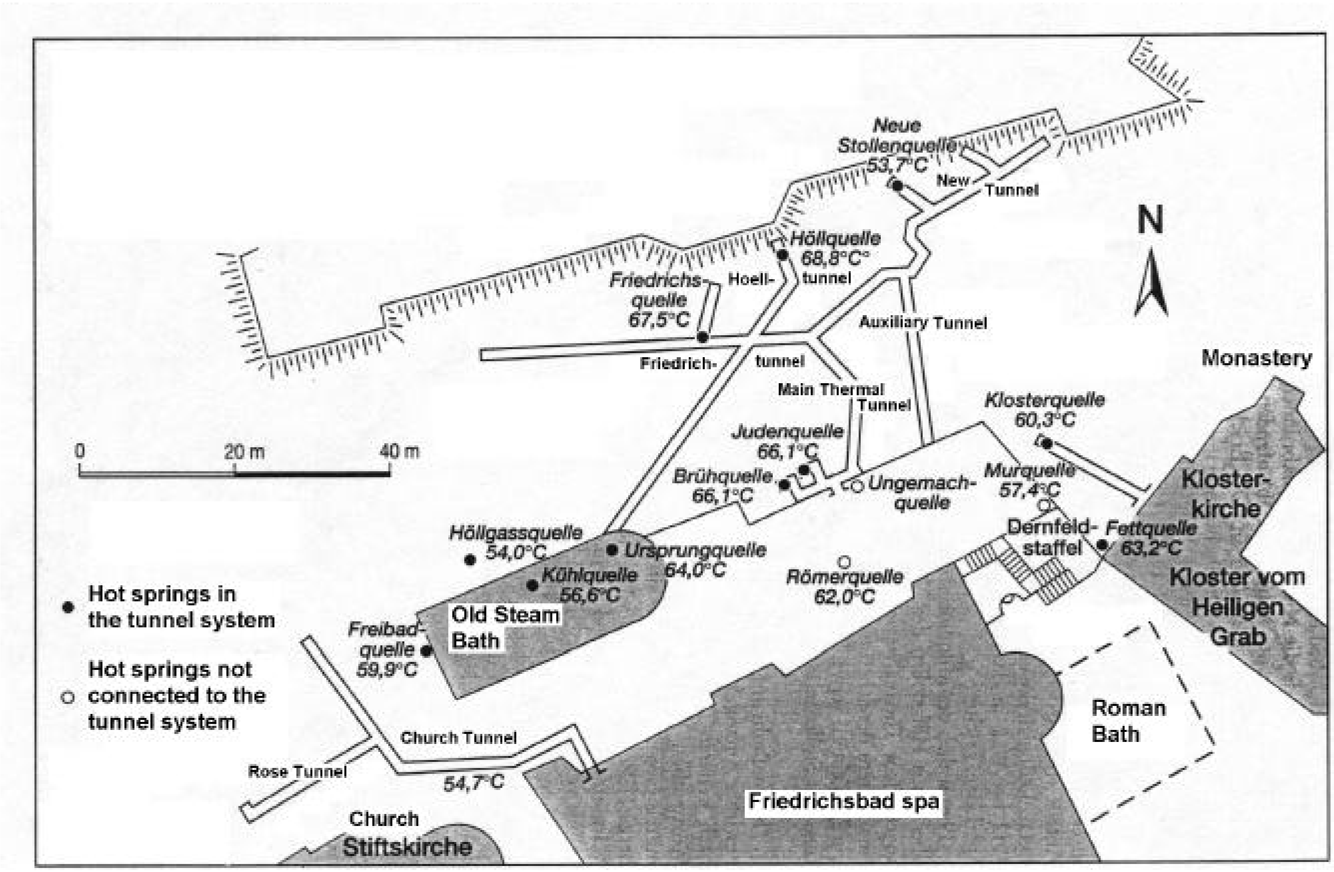


Figure 4. ***The catchement works and tunnels built from 1868-1902, with source temperatures (...quelle = spring, source; from Landesarchiv BW, 1995).***

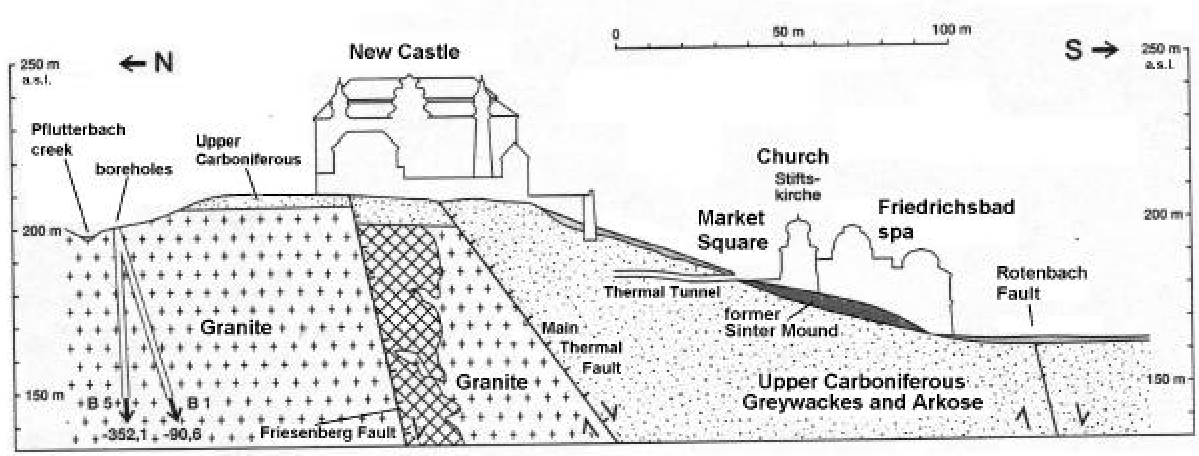


Figure 5. ***Profile through the main thermal area in Baden-Baden (after Bilharz, 1934; from Landesarchiv BW, 1995).***

Table 1. Analysis (selection) of Water from Friedrichs-Tunnel, Sample of July 14, 1987 (after data from Landesarchiv BW, 1995)

Kations	mg/kg (ppm)	Anions	mg/kg (ppm)
Sodium	850.66	Chloride	1437.60
Potassium	75.05	Bromide	3.10
Lithium	9.03	Iodide	0.00
Calcium	129.35	Fluoride	4
Magnesium	2.07	Nitrate	5.40
Strontium	1.71	HCO_3	0.18
Rubidium	2.50	Sulfate	155.10
Caesium	2.20		152.81

Temperature: 64.6 EC (148.3 EF) pH-Value: 7.47

was drilled with an angle to the south, and the bottom in 301.5 m (990 ft) depth is in fact beneath the court of the new castle (Figure 6). The second borehole is 552.5 m (1812 ft) deep and vertical.

Both wells penetrate other layers than the existing springs come from (north of the Friesenberg-fault, see Figure 6 and cross-section in Figure 5). However, temperature and chemistry of the artesian water found here are similar to the springs. The production decreased from 1.8 l/s (28.5 gpm) in the beginning to 0.94 l/s (14.9 gpm) in 1991. The wells (Florentiner-source) are now part of the thermal water system (Figure 6).

In 1973/74, a deep borehole was drilled in the graben to the west of the city, following seismic profiling (Vibroseis) the year before. The target horizon was Muschelkalk (mid Triassic) limestone, were thermal water was expected. The borehole went trough 85 m (279 ft) of Quarternary material, followed by Tertiary material down to a depth of 1855 m (6086 ft). Under a fault, Jurassic sediments were found. At another fault in 2180 m (7152 ft) depth the Jurassic ended abruptly, and lower Triassic sediments followed. From 2440 m (8005 ft) to the bottom of the borehole at 2721 m (8927 ft) depth the metamorphic bedrock was perforated.

Due to the tectonic omission of Muschelkalk, no water could be found. The borehole was filled in 1975, and seismic investigation resumed. In 1976-77, a second deep borehole was drilled. The stratigraphy in this hole was: Quarternary material down to 70 m (230 ft) depth, followed by Tertiary material down to 1040 m (3412 ft). Under a fault, sediments of the Jurassic were found, and from 1311 m (4301 ft) to the final depth of 1502 m (4928 ft) upper Triassic (Keuper) prevailed. From 750 m (2464 ft) depth a small amount of water (0.02 l/s or 0.32 gpm) was produced, with 14910 mg/l (ppm) of Chloride. The drilling was stopped when the rig reached its maximum lifting capacity, and the hole was eventually filled in 1978. After these experiences and a lot of money spent for deep drilling, no further activities were done to explore deep thermal waters.

The geothermal gradient in the second of the deep holes was measured to 5.1EC/100 m (2.8EF/100 ft). This looks promising for the use of geothermal energy, if either water could be found or technologies from the Hot-Dry-Rock-development could be used.

THE BATHS TODAY

The thermal water today is produced by three sources:

- tunnels comprising several former springs
- some remaining individual springs
- two drilled wells

The temperature and production of these sources is listed in Table 2.

Table 2. Properties of the Individual Sources in Baden-Baden, April 1993 (after data from Landesarchiv BW, 1995)

	Production		Temp.		TDS*
Source	m^3/day	gal/day	°C	°F	mg/kg (ppm)
Tunnels					
Friedrich-tunnel	384	101453	66.9	152.4	3013
Kirche-tunneln	71	18758	54.7	130.5	2778
New tunnel	22	5812	58.9	138.0	2692
Springs					
Ursprungquelle	113	29855	67.1	152.8	2999
Kuehlquelle	29	7662	59.8	139.6	2851
Freibadquelle	9	2378	59.6	139.2	2811
Fettquelle	62	16380	63.7	146.7	3041
Murquelle	6	1585	54.1	129.4	3072
Klosterquelle	10	2642	57.4	135.3	2898
Hoellgassquelle	8	2114	52.6	126.7	2833
Wells					
Florentiner 1	54	14267	60.1	140.2	2680
Florentiner 2	27	7133	51.6	124.9	3522

TDS: Total Dissolved Solids

Two major bathing facilities dominate the activities in Baden-Baden today. One is the traditional Friedrichsbad, serving relaxation and healing since more than a century, and the other is the relatively new Caracalla Spa. Both are supplied with thermal water from the traditional hot springs as well as from the two wells drilled in the 1960s (Figure 7). Thermal water is also delivered to three public drinking fountains and several private users (hotels, hospitals). The annual consumption is shown in Table 3.

Friedrichsbad was opened in 1877 in the traditional hot springs district, just beside the traces of the Roman bath and partly on the site of the former sinter mound of the hot springs (Figures 4 and 5). It features a unique combination of Roman and Irish bathing tradition, initiated by Dr. Barter, an Irish physician, who combined the Roman approach (various types of warm thermal baths) with the traditional Irish technique (hot air baths).

Healing effects of Friedrichsbad´s Roman-Irish baths are used to treat chronic disorders, such as arthritis or rheumatism of the joints. Vegetative circulatory disorders, chronic bronchitis, paranasal sinus problems, obesity and

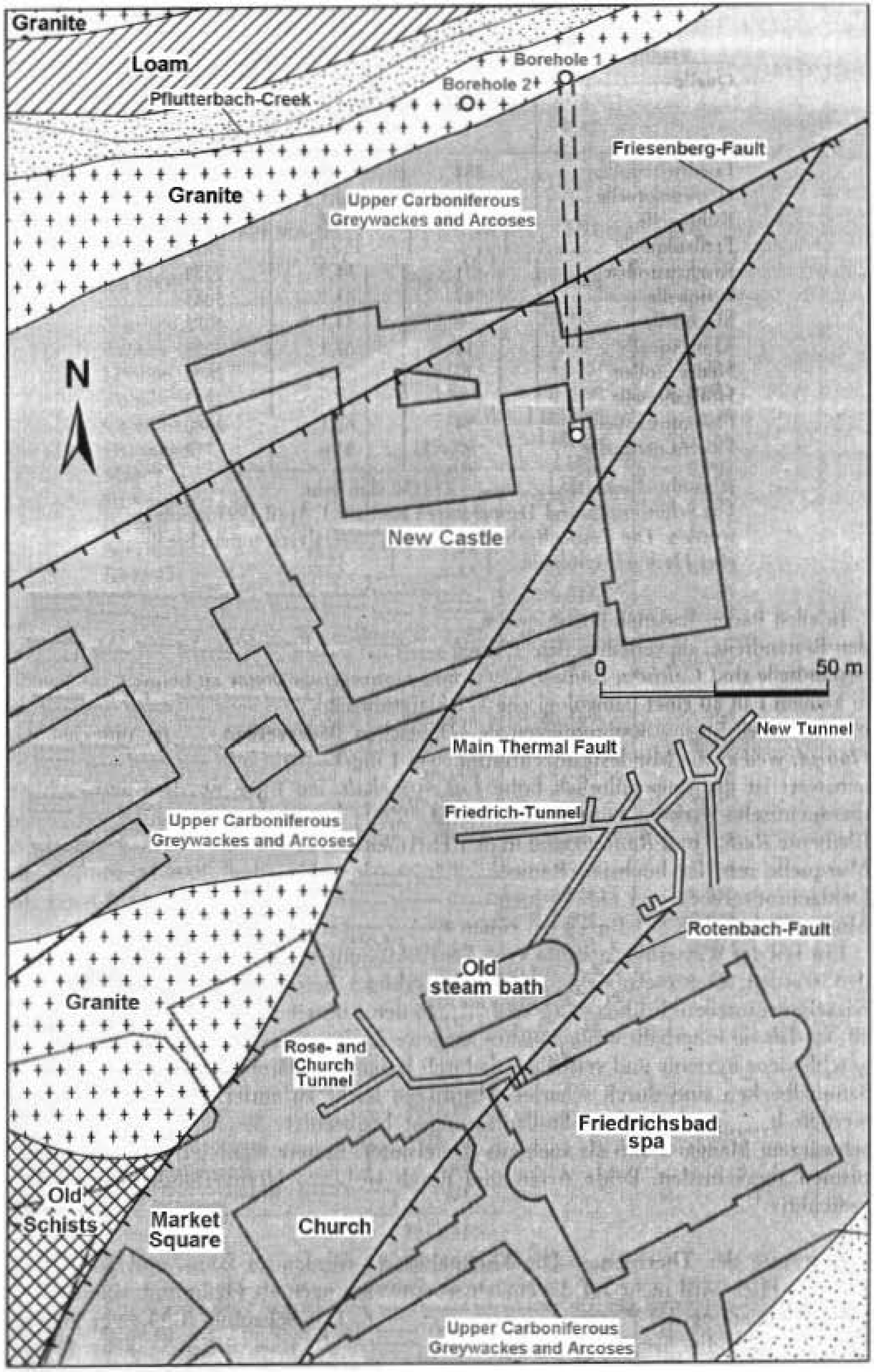


Figure 6. ***Geological and tectonic map of the main thermal area (after Maus & Sauer, 1972; from Landesarchiv BW, 1995).***

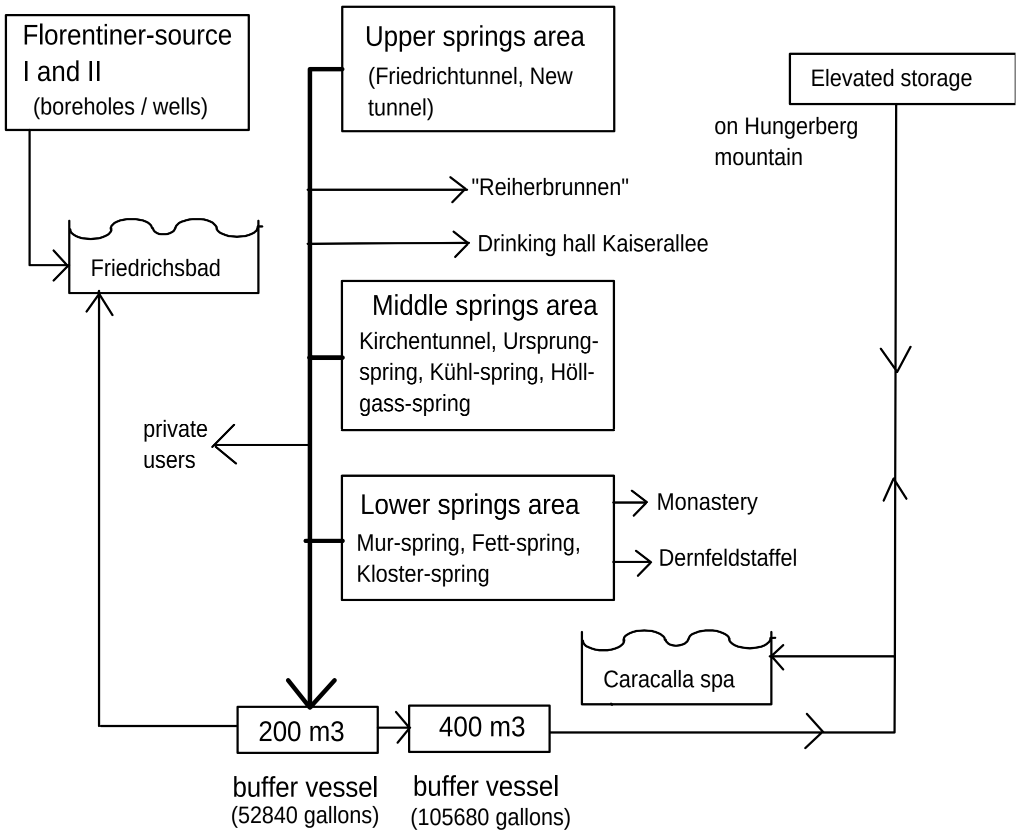


Figure 7. **Schematic of the thermal water production and use in Baden-Baden, after Landesarchiv BW (1995).**

Table 3. Annual Consumption of Thermal Water in Baden-Baden (after Landesarchiv BW, 1995)

Thermal Water Consumer	**m^3/yr**	**gallons/yr**
Caracalla spa, with drinking well and part of hospital	165,244	43.7 mil.
Friedrichsbad Spa	83,621	22.1 mil.
Drinking hall at Kaiserallee	876	0.2 mil.
"Reiherbrunnen" drinking well, Sophienstrasse	3,311	0.9 mil.
"Fettquelle" drinking well, Dernfeldstaffel	1,167	0.3 mil.
Private users (hotel & hospitals)	37,931	10.0 mil.
Total	**292,150**	**77.2 mil.**

various glandular disorders can also be beneficially influenced (information from Carasana Bäderbetriebe GmbH, operators of Friedrichsbad).

The Caracalla Spa, located in the city center and opened in 1985, features a large indoor pool (32EC/90EF) with its own therapeutics area, two open-air pools (30 and 34EC/86 and 93EF), one cold and one hot water grotto (18 and 38EC/64 and 100EF), with a total area of more than 900 m^2 (9690 sq feet).

ACKNOWLEDGMENTS

Many thanks to Peter Schellinger, Baden-Baden City Authorities, for the tremendous help in providing necessary information for this paper. Further information form the official homepage of the city of Baden-Baden was used: http://www.baden-baden.de/.

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BAD SCHINZNACH, AN ONGOING GEOTHERMAL SUCCESS STORY

EMISSION-FREE ENERGY AT A HISTORICAL BUT INNOVATIVE HEALTH RESORT SAVES 1,400 TONNES OF CO_2 ANNUALLY

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In northern Switzerland, where the Aare River cuts across the Jura Mountains, people have known about the warm upwelling waters in the banks of the Aare River for ages (Figure 1). However natural changes of the braided river bed made locating the upwelling source of warm water difficult and the source was lost over various periods of time. Since the 17th century, the Schniznach spa has been used commercially and became a well known resort for health treatment, and a resort for social and political conventions.

Only at the beginning of the 20th century was a proper well sunk to a depth below the river bed to capture the thermal water. There the thermal water could be tapped directly from the underlying karst aquifer of Triassic limestones, the so-called Upper Muschelkalk. The shallow well served the Schniznach spa for over 80 years. The temperature and the chemistry of the thermal water was, however, diluted with cold and weakly mineralized groundwater from the Aare River. In 1980, in the course of a systematic regional study of the geothermal potential, an exploratory well was drilled at the Bad Schiznach site. The well produced about 10 l/s with an initial temperature of around 34ºC from karstic limestones at a depth of 72-78 m. The well produced reliably over the next 15 years. In the course of time, near surface groundwater increasingly seeped into the aquifer and cooled the source down to a mere 26ºC. The regional study revealed a mixed origin o the thermal water. Current interpretations from geochemical fingerprinting point to three sources: a distant transport from underneath the Molassse Basin fed by an alpine intake area, an upward flow along the Permocarboniferous trough margin and some surface inflow from the Jura Mountains (Figure 2).

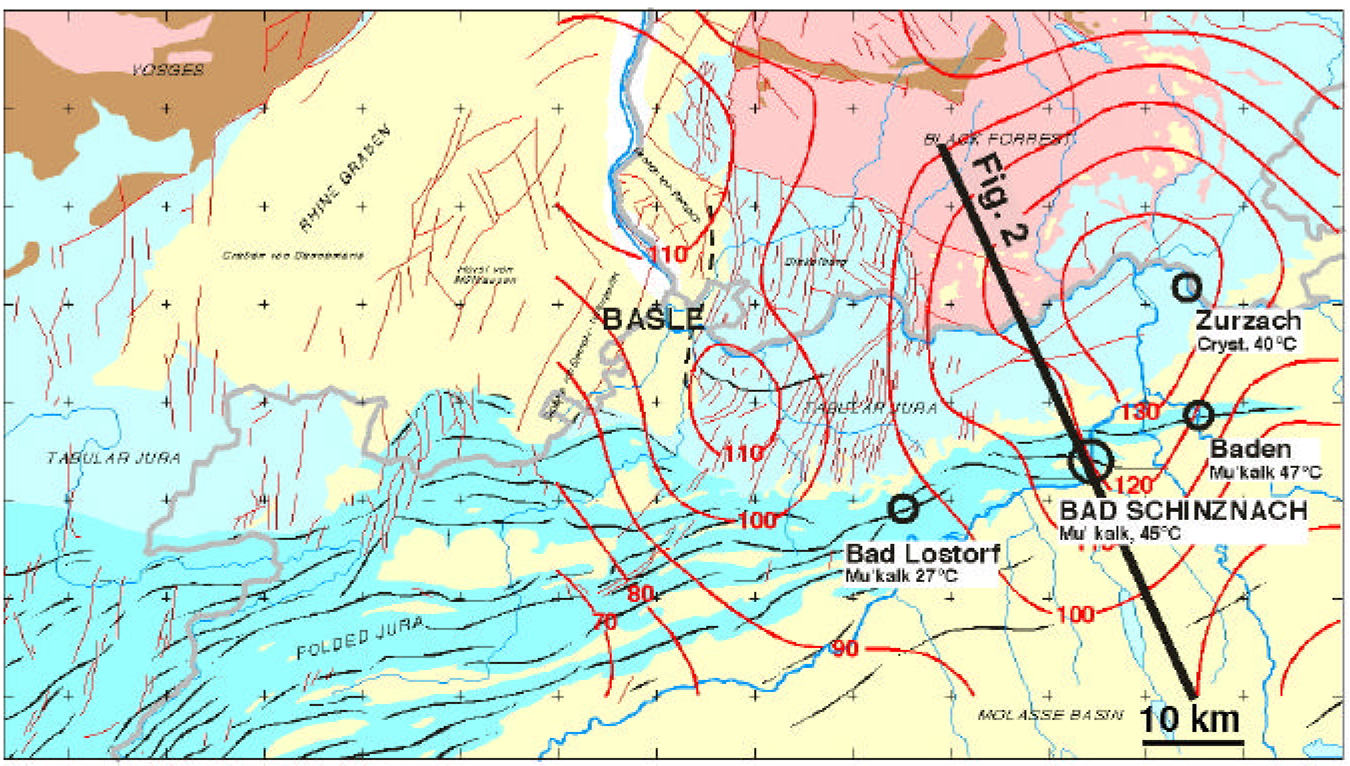


Figure 1. Regional geology and heat flow contours (mW/m²).

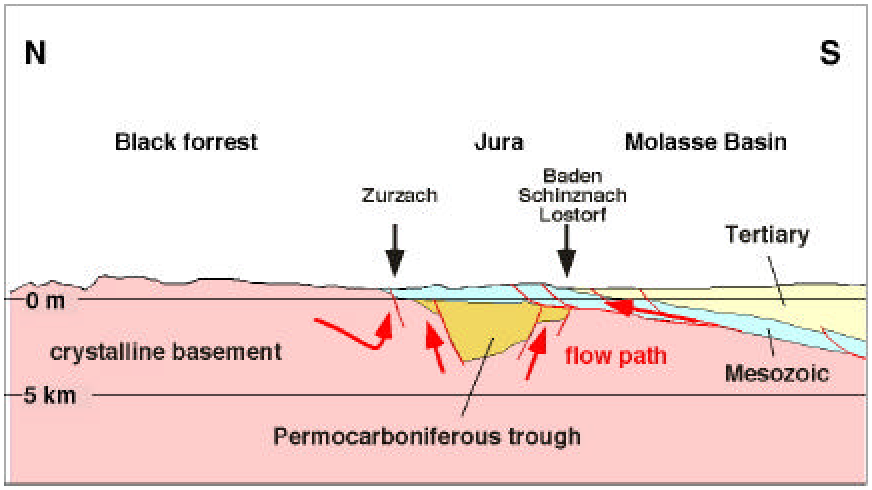


Figure 2. N-S cross section northern Switzerland and situation of thermal springs.

The newly built "Aquarena"–an attractive in- and outdoor pool area–required an increased and continuous supply of warm water as well as thermal energy for heating and air conditioning. According to its owner, the spa area–situated in a pleasant green surrounding–ought to be supplied with sustainable and emission-free energy. So the target was set to develop a geothermal well with a source capacity of 1 MW. The idea was to tap the known aquifer in a downdip position in order to produce water at higher temperatures and protected from the influx of cold surface water. It was further intended to produce the water not only for balneological purposes, but also as a heating source. In contrast to the previous utilization, this demand required a reinjection scheme.

The structural situation was investigated by a small seismic survey. The survey revealed that the outcropping Upper Muschelkalk is the top limb in a complex overthrust, overlying a detached silver of upper Muschelkalk and its autochthonuous part. The drilling location was selected under the criteria of minimal distance to the spa and maximum depth of the aquifer. At the selected well location, the aquifer could be tested at three different levels (Figure 3).

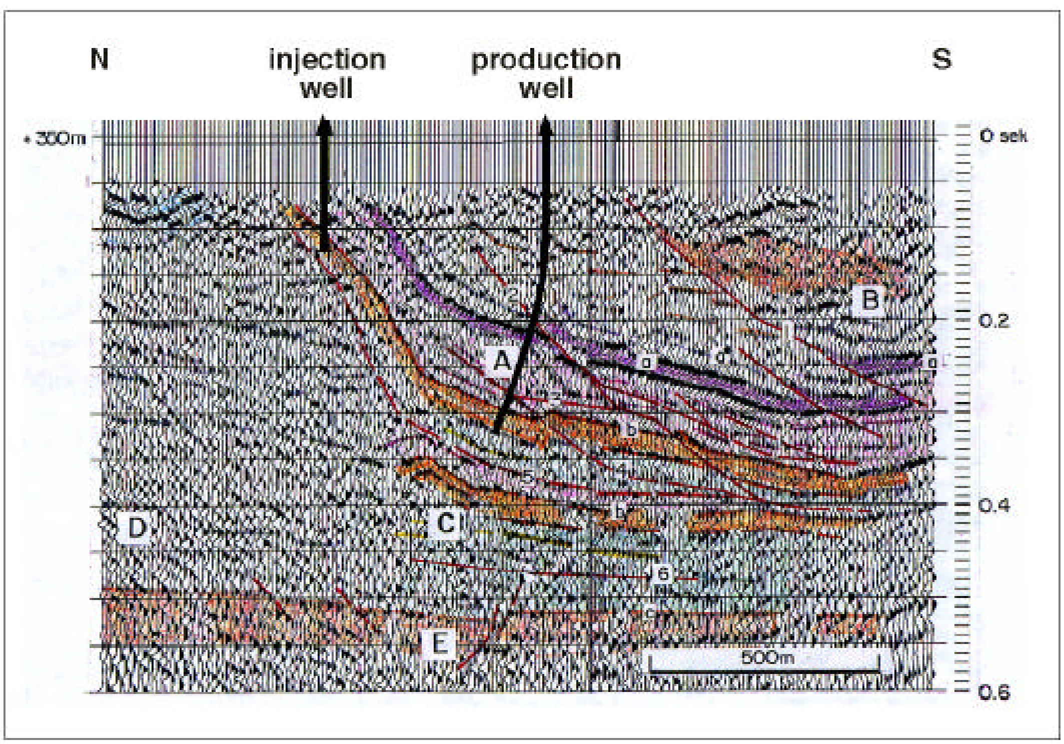


Figure 3. Migrated time-section with well traces (seismic interpretation by P. Diebold).

The well encountered the Upper Muschelkalk as expected at three levels, however, with very different hydrological characteristics. The uppermost limb produced thermal water with a temperature of 45°C and the characteristic Calcium-Sodium-Sulfate-Chloride mineralization of the old Schniznach wells. The characteristic hydrogen sulphide concentration does not exceed 56 mg/l which is slightly less than in the old wells. In order to increse the initial flow rate, the well was acidized resulting in a sustainable production of 8.5 l/s with minimal drawdown and a peak production of up to 21 l/s. The deeper limbs of the Upper Muschelkalk produced much less water, but with temperatures of up to 64°C. However, the mineralization–mainly sodium chloride–exceeded 20 g/l which renders these flow levels commercially unattractive. The different mineralization suggests that the deeper levels of the upper Muschelkalk are detached from the upwelling aquifer. But with the production from the top level, the target of a geothermal source of 1 MW was already clearly achieved. In a next step, reinjection into the old well was tested successfully. The reinjection scheme serves the double purpose of maintaining the hydrological balance and shielding the aquifer from the influx of cold near surface groundwater (Figure 4).

A 500-kW heat pump extracts 17°K from the geothermal cycle and produces 4.5 GWh of emission-free thermal energy annually (Figures 5 and 6). The system substitutes now more than 450 tonnes of heating oil and reduces CO_2 emissions by 1,400 tonnes annually; a considerable environmental contribution to an attractive location dedicated to health and wellness. An oil peaking system provides 1.5 GWh annually. The oil heating system is utilized when the outside temperatures drops below about 15°C and is used extensively when the temperature is below about -8°C.

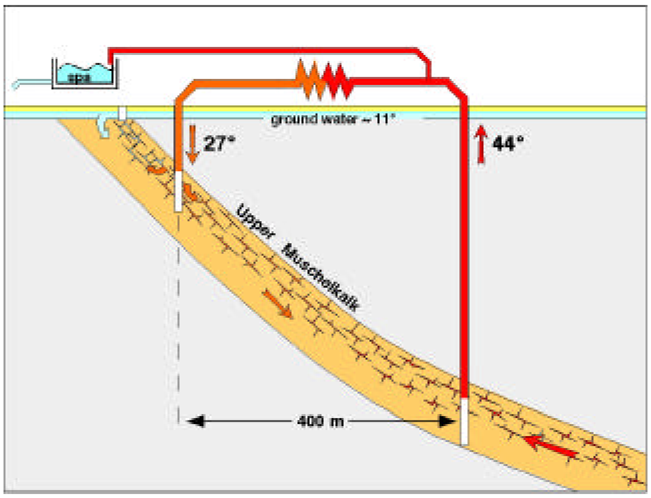


Figure 4. Geothermal doublette at Bad Schniznach.

Figure 6. Heat pump equipment room.

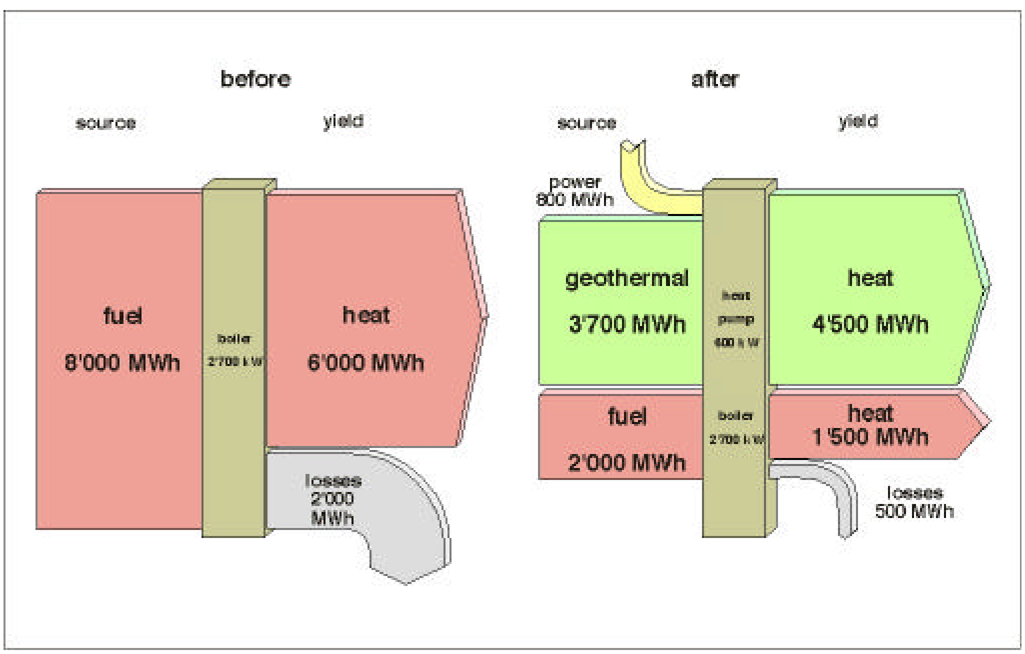


Figure 5. Heat supply at Bad Schniznach: old conventional vs. new combined geothermal.

The Bad Schniznach area has a number of facilities devoted to health and fitness. These can all be accessed on the Internet at: www.bad-schniznach.ch. The main pools heated by the geothermal waters are call Aquarena and consist of an outdoor pool of 600 m^2 at 35ºC supplied by a waterfall (Figures 7 and 8), an indoor pool at 35ºC and a soaking pool at 37ºC. The facility also has a sauna, a solarium, restaurant, and offers massages. A private bath, Thermi, located in a large building was built in 1760. This facility has a 200 m^2 outdoor swimming pool with massage jets located around the perimeter. The private clinic (Private-Klinik im Park) for physical therapy and a Kurhotel for the treatment of rheumatism are also located in the community. To add to the enjoyment of the area, a wooded area with many hiking trails are also available. Some of the trails are called “Geo-Weg” describing the geology of the area. As in most European countries, the trails distances are given in time rather than kilometers (Figure 9).

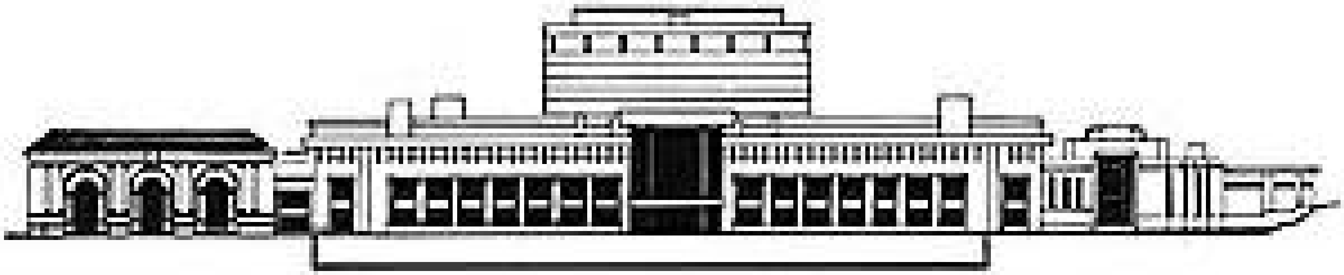
Figure 8. Aquarena–inside pool.

Figure 7. Aquarena–outside pool.

Figure 9. Sign post in hours (std.) and minutes (min).

LES THERMES D'AIX-LES-BAINS

Edited by John W. Lund
from www.aixlesbains.com



Aix-Les-Bains, a prestigious spa town, is located at the heart of the Savoie Olympic region on the edge of the Le Bourget lake, the largest natural lake in France. The town is located approximately75 km south of Geneva and 90 km east of Lyon near the Italian-Swiss border. It is a town of 26,000 inhabitants with Mt. Revard (1,550 m) overlooking the town and with a view of Mt. Blanc in the distance. One of the famous visitors to visit the region was Queen Victoria, who came incognito under the title of Countess of Balmoral. She liked the waters and the climate of Aix so much that in 1888, she wanted to buy a domain on a nearby hill to build a second home. This plan did not come to fruition.

EARLY GEOTHERMAL DEVELOPMENT AND USE

It was Celtic horsemen who first discovered the hot, healing springs on the slopes of Mt. Revard. They placed them under the protection of Borvo, their God of Healing. After the Romans had subjugated the Gaule Narbonnaise region around 120 BC, they baptized the city Aquae Grantianae and constructed the comfortable thermal baths then in fashion in the Empire. Patricians from the Roman Gaule Provincia region came to bathe here. First they took a hot bath (*caldarium*) then a warm bath (*tepidarium*) and then a cold bath (*frigidarium*). All the pools were marble and the rooms decorated with columns and sculptures. They were heated by underground channels called *hypocaustes* containing hot air.

The tradition of taking baths in the hot springs was continued through the centuries under the reigns of the Burgundian, Frank, Merovingian and Carolingian kings. Aquae became Aix. In 1600, Henry IV "took a bath for one hour" in the only bath still accessible, the Royal Bath. In 1623, Doctor Cabias published a book on the "marvellous virtues of the baths at Aix-en Savoye." The high-born could baths at home in thermal waters brought to them by carriers, but most patients bathed in the grottos where the Soufre and Alun springs gushed forth from the rock. Water can be seen coming up to the surface today through a tunnel dug in the rock in the XIX century. Its underground journey from the opposite side of the lake takes more than 30 years and comes up from a depth of 2,000 m at a temperature of 46ºC.

NATIONAL GEOTHERMAL DEVELOPMENT AND USE

In 1776, the King of Sardinia, Victor-Amedée II decided to give Aix baths worthy of the quality of its water. In 1784, he inaugurated the Etablissement Royal des Bains. The one became quickly too small, thus, at the beginning of the XIX century it was enlarged and new baths, a large swimming pool and a *vaporarium* (stem bath) were built. Zinc bath tubs were installed and new techniques invented: rain baths, the "*douche écossaise*" (cold showers) and a massage shower. Aix treated nervous diseases, syphilis and rheumatism. Restoration and enlargement in 1857, 1934 and 1970 have resulted in the present establishment which specializes in rheumatology. Attendance has risen since spa treatments have been covered by the french national health reimbursement system.

THE GEOTHERMAL WATERS OF D' AIX-MARLOIZ

The sulphureous water of a small stream running through Marlioz was known by the inhabitants of Aix to cure acne and mild skin disorders. The water was analyzed, controlled and in 1861 the Prefet of Savoy, Mr. Dieu, inaugurated the new thermal baths and springs of Adélaide, Esculape and Bonjean. Reconstructed in 1982, the Aix-Marlioz baths treat disorders of the ear, nose and throat, and various allergies.

RHEUMATOLOGY

The massage shower or "Aix shower" is the characteristic treatment of the Thermal spa. It combines a general massage under a spray at constant temperature and a terminal shower jet. It is a general treatment leading to a circulatory stimulation. It can be preceded by a warm shower coming from a watering rose of large diameter, given in a steam-room atmosphere, called "bouillon". The under-water shower takes place in an individual bathtub with a variant, the suspended bath, which support a patient with limited mobility. The applications of mud thermo-vegeto-minerals are made of a maceral argillite in the thermal waters which transforms the calcareous clay into a plastic state. The Berhollet is a warm air bath humidified by the thermal waters. The equipment provides a stray of water on various portions of the body. Hydrotherapy showers are also available.

POOLS

Various pools are available ranging from 33 to 36ºC, with soaking times varying from 10 to 20 minutes, depending upon the treatment. These are used mainly from the treatment of rheumatism and for the recovery from various injuries such as for joint mobilization.

BALNEOTHERAPY

The Phytomer Center, the Aqualioz-Thalgo Espace and the Adelphia Baths all have a fitness area with heated swimming pools, sauna, stream baths and hydromassage, a therapy area, a beauty center and various specialized treatments.

PRESENT DEVELOPMENT

Today the Chevalley Baths is investing 307 million francs (44.5 million US$) in one of the largest building sites in The Rhône-Alpes region. The aim is to complement the treatments already offered by the National Baths and to reinforce Aix-les Bain's renown in the treatment of rheumatism. Other developments include a Great Lake project with improved access to the lake and new bath areas, viewpoints and walks. Aix-les-Bains will modernize the nineteenth century baths, rehabilitate the esplanade and also renovate the water sports center and the aquarium. Additional details on the baths and the town can be found on their website: www.aixlesbains.com.

SPAS IN JAPAN

Theodore B. Van Itallie, M.D. and Leila Hadley
Edited from: *The Best Spas*, Harper & Row, NY (1988)

In Japan, there are over 10,000 thermal mineral springs, more than in any other country in the world, and over 2,000 hot springs, or *onsen*, resorts. Some of these are located in isolated mountain villages. Others are large pleasure resorts served by Western-style or Japanese-style hotels, the traditional *ryokans* (inns).

Rylkans are uncluttered, spartan to western eyes. Your *tatami* (straw mat) room comes with low tables, translucent *shoji* screens, which usually slide open to an appealing vista, as airy an environment as a birdcage to some, and forlorn as a dungeon to others who prefer a canopied four-poster to a *futon* (cotton or down quilt) placed on the floor for sleeping. Luxury-level *ryokans* may feature lacquer furnishings inlaid with mother-of-pearl, a *kokatsu* (a table with a heat lamp and quilted padding like a tea cosy to keep the heat from escaping), heated toilet seats, and other niceties. In all, you are provided with a *yukata* (sleeping kimono) of cotton for summertime wear or lined with wood for winter use, slippers for walking inside, and *geta*, or rectangular, elevated wooden clogs 2 to 4 inches high, with a strap for your toes, for outdoor walking. (Editor's Note: However, none fit my large–size 12–western foot.)

At some spa locations, massage and acupuncture treatments are available. Relief from ailments is promised through soaking, warming, and relaxing in your own private high-sided, vat-like bathtub, or by taking *o-furo*, a steaming soak in a wooden or stone pool brimming with mineral water in a public bathhouse. One of Japan's deeply rooted traditions is mixed male and female nude bathing, in the steam bath, but many *ryokans* have separate facilities.

Beppu is a seaport on the southern main island of Kyushu, in the prefecture of Oita. (Editor's Note: It was one the recent sites for the World Geothermal Congress 2000 held in May/June 2000. Also, see Vol. 17, No. 2 (1996) of the *Geo-Heat Center Quarterly Bulletin* for more on Beppu Hot Springs.) Its scenic valleys and hills proffer a variety of natural spring baths, from steaming hot mineral water spouting from more than 4,000 openings–some spurting up smack in the center of town–to the muddy, bubbling oozing of a furmarole's "hell pond," some vermilion, some deep blue, said to stimulate a clear complexion and to heal arthritis, bronchitis, and circulatory problems with a week's daily 30-minute treatments. This therapy is experienced outdoors, so that while you let the hot mud slurp around you–the less your move, the more heat you can stand, and the longer you can endure lolling about in it–your can look upward at lush and undulating green hills in the distance and admire the charm close up of a wooden bridge garlanded with seasonal flowers. The bridge leads to the bathhouse where you use buckets of water and soap to cleanse yourself of your mud coating before you slide into the communal bath. (For all communal baths, you always soap yourself and rinse off several times before you are considered clean enough to get in.) (Editor's Note: Beppu is also the location of numerous "hells" or *jigokus* which are hot spring tourist parks.)(Figure 1)

Figure 1. Jigoku in Beppu.

Less messy, but just as therapeutic, said to promote active circulation and to help sufferers of gastrointestinal ailments, neuralgia, and rheumatism, are the natural hot sand baths at one of Beppu's oldest establishments, which first opened for serious sand bathers in 1879. The sand, rich in sulphur, is layered above a hot spring and heated to a temperature of 140°F, both by the hot water rising through the sand and by the steam the water releases to vaporize in the air. An attendant buries you up to your neck in heated sand for a short stint while your body is treated by the underground spring below as well as by a hot mineral spring after-bath.

The giant Suginoi Hotel has 508 Japanese-style rooms, 89 Western-style rooms, all with private baths. (Editor's Note: The Suginoi Hotel also has two large bathing areas available for guests–one for men and the other for women (Figure 2). So as to let the guest enjoy both facilities, the gender use is reversed on a daily basis. There is also an Aquabeat facility across from the hotel that includes water slides, jacuzzi, dream bath (*umeno onsen*), flower bath (*hana-no onsen*), outdoor hot spring baths, a wave pool, theater, bowling alley and restaurant. A 3,000-kW geothermal power plant, put into operation in 1980, supplies electricity to the hotel. The waste water from the plant is cooled by cascading down through a park behind the hotel.)(Figure 3)

Noboribetsu Onsen, on the island of Hokkaido, is a spa resort located in a narrow valley among wooded mountains. A sanctuary for brown bears on the top of nearby

Figure 2. ***Hot spring bath in the Suginoi Hotel, Beppu.***

Figure 3. ***3,000-kW geothermal plant at the Suginoi Hotel.***

Mt. Kuma and a close-by village of Ainu folk is of interest to most visitors. It is noted for its Valley of Hell, a huge indentation in the earth from which various types of sulphuric, salt, and mineral waters and muds spout, gurgle, and steam for the health and relaxation of its patrons.

Spa areas of particular appeal to Westerners include Nikko, in the Tochigi Prefecture northeast of Tokyo; Kusatsu, in the Gumma Prefecture northwest of Tokyo; Hakone, just to the south of Tokyo in the Kanagawa Prefecture; Katsuura and Shirahama in the Wakayama Prefecture convenient to Nara and Osaka; Arima in Hyogo Prefecture convenient to Kyoto; Dogo, in the Ehime Prefecture, convenient to Nara and Osaka; and Unzen in Nagasaki Prefecture on the tip of the island of Kyushu opposite to Oita. Nikko is located by Lake Yunoko in Nikko National Park. You get a great view of Mt. Fuji in the Hakone area. At Katsuura, the Nachi waterfall is a 25-minute bus ride away, and you can cruise around the Kino-Matsushima islets. Kusatsu is located near a notable ski resort on the flanks of Mt. Shirane. Zao Onsen in Yamagata Prefecture in the northern highlands is also located near a ski resort, with choice deluxe accommodations as well as venerable *ryokans* comprising thatch-roofed buildings connected to each other, allowing them to share hot sulphur springs that pour out of the mountainside into steaming pools in each inn, often reachable from open verandas. In some, time-worn green and black stone baths for communal bathing are kept constantly brimming by cool, warm, and hot water spouts you can stand under like showers. A large room with an entry foyer--lanai set with a wicker table, chairs, and a toilet–the location of privies in country *ryokan* architecture may involve walks through labyrinthine corridors, so this placement is considered a luxury.

Your best bet for a first Japanese spa experience might be Atami, a scenic resort perched on the slopes of an extinct volcano overlooking Sagami bay, about 55 minutes south of Tokyo by Kodama Express to JR Atami Station. Popular since the 18th century, when Japan's shoguns made their ceremonial way down the Tokkaido Road to Atami's waters–rich in calcium, magnesium, and other minerals said to be good for relieving bronchitis, constipation, eczema, and indigestion, and aiding relaxation and relief of anxiety–Atami, often referred to as Japan's Rivera–minus beach–is a favorite spot for lovers, honeymooners, and company-sponsored parties and outings.

The amenities of a true *ryokan* do not include a restaurant or a dining room. If you are attuned to American spa resort hotels, with planned activities, playgrounds, gymnasiums, and tutors, you may be bewildered by the Japanese penchant for solitude and seclusion, but in Japan, solitude is considered to be a status symbol, and nowhere better to be enjoyed in Atami than at Horai. Trained in shiatsu and other forms of massage, licensed masseurs and masseuses are available by appointment to come to your room to relax and tone your body. Each of the 17 suites at the Horai is equipped with a square cypress-wood bathtub for you to steam in up to your chine, perhaps for half an hour before dinner. But to miss the communal co-ed bathhouse is to bypass the grand passion of the Japanese–immersion in water so hot as to be barely tolerable, keeping still so that the hot water does not hurt, a sacramental ritual of regeneration. You'll also miss the exercise of negotiating the steep covered walkway down to the ancient-style bathhouse, with slots and joints instead of nails and screws holding its cypress roof beams together above the granite tub brimming with water kept at a temperature of 108°F. Your wooden *geta* make the trek down and up the stone steps an excellent exercise for your leg and foot muscles. Yoshi Furutani, the proprietor's wife, and Yukimasa Kinjo, the assistant manager, explain that guests do not come to Horai for the stair-climbing exercise, or for the healthy diet, but for the therapeutic qualities of the water, the view, the peace, and the solitude.

For more information about Japanese spas: Japanese National Tourist Organization, 630 Fifth Avenue, New York, NY 10019; telephone (212) 757-5640, or through their website: www.jnto.go.jp and then search for "hot springs and spas."

BALNEOLOGICAL USE OF THERMAL WATER IN THE USA

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INTRODUCTION

In the United States, the use of natural springs, especially geothermal ones, have gone through three stages of development: (1) use by Indians as a sacred place, (2) development by the early European settlers to emulate the spas of Europe, and (3) finally, as a place of relaxation and fitness.

The Indians of the Americas considered hot springs as a sacred place of Wakan Tanka ("Great Mystery" or Great Sacredum" in the Lakota language) and thus, were great believers in the miraculous healing powers of the heat and mineral waters. Every major hot springs in the U.S. has some record of use by the Indians. They were also known as neutral ground, where warriors could travel to and rest unmolested by other tribes. Here they would recuperate from battle. In many cases, they jealously guarded the spring and kept its existence a secret from the arriving Europeans for as long as possible. Battles were fought between Indians and settlers to preserve these rights. The early Spanish explorers such as Ponce de Leon and Hernando DeSoto were looking for the "Fountain of Youth," which may have been an exaggerated story of the healing properties of one of the hot springs.

The early European settlers in the 1700 and 1800s, found and used these natural hot springs, and later realizing their commercial value, developed many into spas after the tradition in Europe. Many individual developments were successful such as at Saratoga Springs, New York; White Sulphur Springs, West Virginia; Hot Springs, Virginia; Warm Springs, Georgia and Hot Springs, Arkansas. However, the U.S. did not have the government, trade unions, social security and a national health insurance program to support these developments. Thus, in spite of the benefits of spa therapy that had been proven successful in Europe and elsewhere in the world, the U.S. lagged behind in the development of these mineral springs even though some were acquired by state and the federal government. By the 1940s, the interest in spas languished, and most of the majestic resorts went into decline and closed.

The health and fitness industry has recently been stimulated by increasing consumer interest worldwide, resulting in high growth in revenues and profits. Health spas and resorts, representing a major part of the health and fitness industry, have grown in popularity and offer high investment potential in the United States. Revenues from spas in the U.S. presently are estimated at $10 billion annually. The number of spa-goers is projected to grow from 31% of the adult population in 1987 to 45% in 1997. The most traditional type of health spa is the geothermal spa, featuring baths and pools of natural hot mineral waters.

This recent interest in hot springs soaking and physical fitness has renewed the development of spas in the United States. This natural way of healing and the "back to nature" movement has in many ways rejected formalized spa medical treatment developed in Europe. In fact, the average person in the United States knows little of spa therapy and its advantages as many of the medical claims have been outlawed in the U.S., and the natural waters have required chlorination or other chemical treatment. The main reason people in the U.S. go to geothermal spas are to improve their health and appearance, to get away from stresses, and to refresh and revitalize their body and mind. Unlike European spas where medical cures of specific ailments are more important, U.S. spas give more importance to exercise, reducing stress, lifting depression and losing weight. A recent interest is the development of "health conservancies" to preserve natural areas for health and fitness activities.

The use of mineral and geothermal waters has developed along three lines in this country: (1) the more plush hot springs resorts with hotel-type services and accommodations, (2) commercial plunges or spring pools and soaking tubs with perhaps a snack bar or camping facilities, and (3) the primitive undeveloped springs without any services (Sunset Magazine, September 1983). Many resorts and natural hot springs have an informal dress code while soaking, including nude bathing. They have satisfied health department requirement for chemical treatment by allowing the water to continuously flow through without treatment. Several publications have been written on the subject, documenting these facilities and their use. In the case of the resorts, two books are available: "The Best Spas" by Van Itallie and Hadley, 1988, and "The Ultimate Spa Book" by Sarnoff, 1989. Plunges and hot springs are well documented in several publications, such as: "Great Hot Springs of the West" by Kaysing, 1990; "Hot Springs and Hot Pools of the Northwest and Eastern States" by Loam and Gersch, 1992, and "The Hiker's Guide to Hot Springs in the Pacific Northwest" by Litton, 1990. Similar publications are also available for other parts of the country.

LOCATION AND CHARACTERISTICS OF THE U.S. SPAS

There are over 115 major geothermal spas in the USA, and many more smaller ones along with thousands of hot springs (1,800 reported by NOAA, 1980). The majority of these are located in the volcanic regions of the western states; but, several famous ones still exist in the east. The major spas are estimated to have an annual energy use of

1.531×10^{12} kJ, or an equivalent of 340 thousands barrels of oil (BOE). Details of some of these U.S. spas are presented in Geo-Heat Center Quarterly Bulletin, Vol. 14, No. 4, March 1993, and in Lund, 1996. Thermal waters in geothermal spas vary greatly in composition from place to place. Table 1 shows some analyses of the major constituents of water from thermal springs and wells in several locations. "N/a" indicate that no value were available and does not necessarily mean that components were absent. Concentrations are in mg/L. The composition of average sea water is included for comparison (Woodruff & Takahashi, 1990).

Table 1. Composition of Waters from Several Locations (mg/L)

	(1)	(2)	(3)	(4)	(5)	(6)
Na	4.0	326.2	520	690.0	290.0	10500
K	1.5	89.6	82	15.0	0.08	380
Mg	4.8	121.6	38	0.2	0.08	1270
Ca	45.0	624.0	150	210.0	34.00	400
Cl	1.8	217.6	n/a	1300.0	106.00	19000
SO_4	8.0	n/a	420	170.0	491.00	2650
SiO_2	42.0	24.0	58	96.0	n/a	n/a
HCO_3	165.0	n/a	n/a	17.0	n/a	140

(1) Hot Springs, Arkansas (2) Thermopolis, Wyoming
(3) Indian Springs, Colorado (4) Belkap Springs, Oregon
(5)Desert Hot Springs, California (6) Average sea water

Interest in spas in the U.S. was not entirely lacking after the turn of the century, as both the federal and state governments became owners and managers of several important ones. Five examples follow (Fig. 1)(Lund, 1996).

Saratoga Springs, New York, located 250 km north of New York City, had approximately 18 springs and hot wells discharging 13°C carbonated mineral water along a fault. The Mohawk and Iroquois Indian tribes frequented the springs during hunting trips in the area. The first written report of the springs by European settlers was in the early 1600s (Swanner, 1988). Since this time, the springs have been used for drinking and bathing, to cure everything from skin disorders to digestive problems. The water and carbon dioxide has also been bottled and sold as a commercial product. Because of use and decline in flow in the springs in the early 1900s, the state of New York formed Saratoga Spa State Park, and now manages the geothermal activity including the only spouting geyser east of the Mississippi River. Several of the older bathhouses, Lincoln and Roosevelt, have been restored providing mineral baths, hot packs and massages. Two commercially bottled water are available: Saratoga Mineral Water and Excelsior Spring Water. The present Saratoga Spa Park has 10 springs with seven other springs located in the surrounding areas of the city.

Figure 1. Location of geothermal spas described in the text.

Warm Springs, Georgia is another famous mineral springs in the U.S. The springs were used by Indians from as far away as New York, as they were on a major trail system. The trails later became military and post roads, with a tavern built in the early 1800s. A number of resorts were built in the area, including the very victorian Meriwether Inn. It is know chiefly for the treatment of polio from the early 1920s to the 1960s. It was promoted by President Franklin Delano Roosevelt, who had polio and established the "Little White House" on the premises in 1932. The Georgia Warm Springs Foundation, who managed the springs, dedicated itself to the conquest of polio. It provided treatment in various pools supplied by warm springs flowing around 58 L/s at 31ºC. With the advent of polio vaccines in the 1950s and 60s, use of the facility declined. Today, the Roosevelt Warm Springs Institute for Rehabilitation of the state of Georgia provides medical rehabilitation and therapy for a broad range of disabilities. The Institute also uses the water for bathing, heating and cooling, assisted by water-to-air heat pumps.

Hot Springs, Arkansas was one of the most popular commercial spas areas in the U.S., created to imitate the development of great spas of Europe. This natural geothermal resource consisted of about 47 springs producing a total of 4 million liters of 60ºC water per day. It is estimated that these hot springs have been used by humans for at least 10,000 years. The "Valley of the Vapors" was an honored and sacred place to the Indians. This was also neutral ground, where warriors of all tribes could rest and bath here in peace--a refuge from battle. Legend reports that Hernando DeSoto, an early American explorer, visited the site in 1541. The springs were developed into a rustic bathing and resort area in the early 1800s. It became so popular with the early European settlers, that it was made into a federal reservation in 1832. By 1878, over 50,000 people visited the springs annually. In 1921, it came under the jurisdiction of the newly formed National Park Service and was renamed Hot Springs National Park. People flocked to this new national park with its large fancy bathhouses along Bathhouse Row. Until 1949, each bathhouse needed to have its own evaporation tower in order to cool the incoming hot mineral water to below 43ºC, the maximum generally tolerated by the human skin. In that year, the Park Service installed air-cooled radiators and tap-water cooled heat exchangers to supply cooled water to the system. Now the bathhouses received two supplies of water: "hot" at 62ºC and "cool" at 32ºC. Of the original 47 springs, only two are presently available for public viewing. Even though activity has declined over the recent years, a full range of options are still available: tub and pool baths, showers, steam cabinets, hot and cold packs, whirlpool, massage, or alcohol rub. Today, the Park leases a number of bathhouses and owns almost 2000 hectars of land.

Thermopolis, Wyoming is located at the mouth of the Wind River Canyon, Approximately 150 km southeast of Yellowstone National Park. The major geothermal attraction in the area is the Hot Springs State Park with the 120 L/s Big Horn Spring. Nearby is the Fountain of Youth resort using natural mineral water from the historic Sacajawea Well flowing at the rate of 60 L/s. At least eight hot springs in the area have created large terraces along the river. These terraces are composed chiefly of colorful lime and gypsum layers known as travertine. The springs, claimed to be the largest mineral hot springs in the world, flow at a temperature of between 22 and 56ºC with a total dissolved solids of 2400 mg/L. The early history of the springs include use by Indians; however in 1896, a treaty was signed between the Shoshone and Arapaho Indians and the federal government which gave the public use of the hot springs. The management of the springs was later turned over to the state of Wyoming forming Hot Springs State Park. Today Hot Springs State Park consists of little over 420 hectars of irrigated lawn and developed area within the 26-square km park, providing geothermal bathing in the State Bathhouse, and free water to six other facilities. Among the facilities provided hot water is a Pioneer Center for retired state residents and the Gottsche Rehabilitation Center specializing in helping stroke victims, closed head and spinal injuries, bed sores, cellulating problems, and burn victims.

Calistoga, California area was originally settled by the Pomos and Mayacmas Indians for at least 4000 years. These early people came from miles around to use the natural hot springs, fumaroles, and heated muds to soothe aches and pains. They also built sweat houses and used the local cinnabar for red war paint. To them, this was the "beautiful land" and "the oven place." In the early 1800s, the Spanish explorers visited the area looking for a possible mission site. They referred to this site as "Aqua Caliente." Sammuel Brannan, in the 1850s, envisioned a resort and spa similar to Saratoga Hot Springs--and thus, the name from a combination of California and Saratoga (Archuleta, 1977). He spent an estimated half a million dollars developing the "resort," with his Hot Springs Hotel opening in 1862. Around the turn of the century, over 30 resorts existed in the surrounding area, including bathhouses, mineral springs, and resort hotels. By 1930, many of these resorts had closed due to financial hardship, fires and lack of maintenance. About 15 years ago, Calistoga again became a "boomtown" with six major spas and resorts in operation. All of these resorts have their geothermal water supplied from shallow wells around 60-m deep with temperature from 77 to 93ºC. The water for the pools and baths is cooled to 27 to 40ºC, and some have mud baths using the local volcanic ash and peat moss. Calistoga also has a mineral water industry and is adjacent to the Napa Valley wine industry.

CONCLUSIONS

Geothermal water has been used extensively for the hot pools and baths, but not for heating or cooling the structures at these spas. Space heating was attempted in the past at many resorts, however, with mixed-to-poor results. Pipes would corrode or plug with deposits and require frequent repairs, replacement and cleaning. The expense was high and thus, "natural" space heating was usually replaced with conventional fossil fuel systems. Today, we at the Geo-

Heat Center, and other geothermal experts, understand and solve these problems on a routine basis. The cost of installing the proper equipment and safeguards are more than offset by the savings in annual heating costs over fossil fuels. The Geo-Heat Center has a technical assistance program funded by USDOE to provide free preliminary engineering and economic design and analysis of any use of a resource for heating and cooling.

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GEOTHERMAL SPAS IN THE CZECH REPUBLIC AND SLOVAKIA

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Over 2,000 mineral and thermal springs have been identified in the former Czechoslovakia. These waters vary in chemical composition and are being used in spa resorts and for bottling. The use of the thermal waters have been traced back before the occupation of the romans, and have a recorded use for almost 1,000 years. Today, there are 60 spa resorts in the two countries, visited by 460,000 patients annually (for an average of three weeks each). About 360 million bottles of mineral water are produced in 22 bottling plants annually. Small amounts of geothermal energy are used in agriculture and for space heating. There is no geothermal power generation due to the low temperature of the resource.

SPA RESORTS

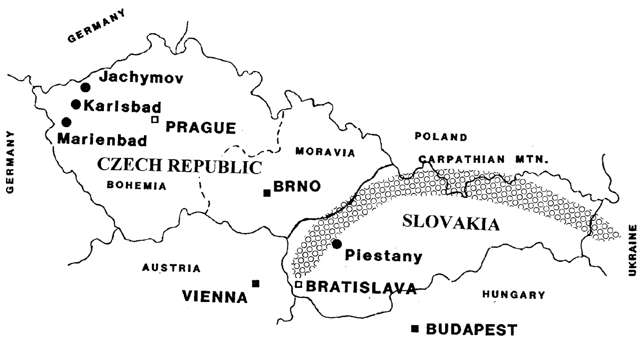

Figure 1. ***Major spa locations in the Czech Republic and Slovakia.***

Czechoslovakia spas have old and well-established therapeutic traditions. Depending upon the chemical composition of the mineral waters and spring gas, availability of peat and sulfurous mud, and climatic conditions, each sanatorium is designated for the treatment of specific diseases. For example, in Slovakia, at Piestany, a special laboratory does all the analysis of water and mud for spas in the region. They make recommendations as to its use, and also perform international work.

The therapeutic successes of these spas are based on centuries of healing traditions, systematically supplemented by the latest discoveries of modern medical science. Most sanatoriums require the referral of a medical doctor (both for domestic and international patients). There are special schools to train doctors in the treatment of patients at spas; five schools in Bohemia for the basic courses, and advanced courses in Prague and Bratislava (65% of the graduates are women).

Two the leading spas are discussed in detail.

PIESTANY SPA

Piestany, located 84 km northeast of Bratislova, is the leading Slovak spa for the treatment of locomotoric system diseases. As many as 40,000 patients yearly, come here to seek relief from rheumatic pains. At present, the spa can treat 3,000 patients per day, with plans to increase the capacity to 5,000 per day.

The use of the hot springs and sulphurous muds for the treatment of rheumatic persons has a very old tradition at Piestany. Archeological finds date settlements in the area to 80,000 years before present, giving rise to the assumption that these healing waters have been used for therapeutic purposes by Neanderthal and Homo sapiens, including Celtic, Germanic and Old Slav civilizations. The settlement was first mentioned in documents in the year 1113, the spa mentioned in 1412, and the first authentic record about its unique effect, found in a letter written in 1546, when it was part of the Hungarian empire. It has attracted many prominent persons of medical science, including the personal physician to three emperors of the Holy Roman Empire–Ferdinand I, Maximillian II, and Rudolph II, and the personal physician to Pope Sixtus V (1571). Many prominent noblemen, maharajahs, sheiks, politicians and crowned heads have been guests at Piestany–including Ludwig van Beethoven and Napoleon who is supposed to have ridden his horse into one of the pools (now call the Napoleon Baths). Bulgarian Czar Ferdinand I used the Thermia Palace as his general headquarters in 1917, where he met with Austro-Hungarian Kaiser Karl I and German Kaiser Wilhelm II to discuss war strategy for WWI. Recent guests include the Indian maharajahs of Bhopal and Hyderbad, and several Arabian sheiks, as well as the wives of the leaders of Austria and Finland.

Initially, visitors bathed in uncovered bathing pits dug along the banks of the river Vah, which were covered by straw mats or tree branches. The first wooden building housing tub baths was built in 1778. Frequent flooding of the river required constant rebuilding of the facilities. Around 1813, accommodations were also constructed on the site, and the spa town improved in 1821. About the same time, Dr. Franz Ernst Schere changed the balneologic treatment procedures based on the latest medical knowledge, and many of his procedures are still followed today. The luxurious spa hotel Thermia Palace and the balneotherapeutic center Irma were completed in 1912, resulting in the spa becoming the meeting place of Europe's elite (as part of the Austrian-Hungarian empire). The spa was privately owned up to 1940, at which time it became the property of the state (Czechoslovakia State Spa and Curative Springs in the Slovak Republic). Fortunately, the spa itself has resisted commercial exploitation, thanks in part to one of its inspectors, engineer Peter Krahulec.

Spa treatment is based on the hot gypsum–sulphuric springs (67 - 69°C) containing 1,500 mg/l TDS, as well as gasses, especially hydrogen sulphide, and sulphuric mud. Thermal water is used in pools and tubs, and the mud is utilized in baths and for mud packs. Hydrotherapy, electrotherapy, rehabilitation and remedial exercises, under-water massage, massage, medications and medial diet are all components of the complex treatment system. Piestany is the seat of the Research Institute of Rheumatic Diseases, founded in 1952 to study the complex immunological processes in the diseases of the locomotor system.

The resources originates at 2,000 m depth and surface springs flow at a rate of over three million liters per day. The spring water is cooled from around 69°C to 35-40°C for use in pools and baths. The chemical composition of the water is: 60.4 mg.l SO_4, 59.6 mg/l Ca, 21.2 mg.l HCO_3, 20.3 mg/l Na, 17.5 mg/l Mg, 17.2 mg/l Cl, and 151 mg/l CO_2. The sulphurous mud is cured six months in an outside storage vault by an anaerobic process to increase the sulphur content. It is also "cooked" for a minimum of 48 hours from 70 to 80°C for the peloids (clay particles) to gain their optimum properties before use.

There are two types of pools: some have a natural bottom with a layer of curative mud through which thermal waters (cooled to 40-41°C) flow. The other type of pool together with the tubs are supplied with thermal water (38-40°C) through a system of pipelines. The sulphur mud is applied in forms of hot compresses by means of modern equipment (spray-gun) or as partial packs on hands and legs in simple wooden vessels at a temperature around 50°C.

KARLSBAD SPA (KARLOVY VARY)

Karlsbad, located 142 km west of Prague near the German border, was founded in the 14th century (1338) by the Bohemian King and Roman Emperor Charles IV (Karl IV), who also bestowed his name on the town. The town is hidden in the valley of the Tepla River, which is framed by wooded hills and precipitous cliffs, such that the town is mostly only one block wide on either side of the river. Geologists believed

that springs, between 35 and 72°C, have flowed for about fifteen million years, and has been used for healing purposes for more than 600 years. There are a total of 132 springs that have been identified, with 12 main ones, producing a total of 2,000 l/min. Tradition says that the "thirteenth spring" is a local alcoholic drink, a herbal liqueur developed in 1807, called *Karlovarska Becherovka*.

The river valley is formed by granitic tectonic blocks which created a rift valley. Subsequent basalt lava flows and aragonite mineralization are also present. The recharge area of the karlsbad thermal water is located in upper granite blocks on both sides of the rift valley. Rainwater flows through fissures down to a depth of more than 1,000 m, where the temperature is more than 100°C (Laboutka and Vylita). Heated water in the accumulation area is saturated with ascending juvenile CO_2 and water vapor. A large aragonite mantel has developed around the thermal springs, caused by the dissolution of CO_2.

The spa is far more commercially developed than Piestany. The original castle, built by Charles IV in the 14th century, was rebuilt in 1608, and a market was constructed in 1883. A Colonnade was constructed in 1911, containing four wells 50 to 90 m deep producing 72°C water (cooled to 30°C). Water from these wells are drunk through the handle of special cups, carried by visitors. This facility also contains a geyser ("Vridlo" or Boiling Source), high in CO_2 (volume ratio of 1:3–hot water to gas) and discharging 100 l/min., with a maximum head of 15 m (it is restricted to 10 m due to the height of an enclosed structure)(Paces, 1988). In addition, a total of 180 tons of mineral salts are produced annually, which are exported for their curative properties. This process has been carried out for 300 years. An estimated 5,000 l/min. Of CO_2 is produced from the entire field, a portion of which is extracted for commercial use. The aragonite and calcite deposits are colored by traces of iron. The chemical sediment is called "Vridlovec," and is used to manufacture jewelry. Small items immersed in the mineral water are soon coated with "Vridlovec" and then sold as souvenirs.

This famous resort where "the devil sprays hot water on the world through a hole in the earth," has been visited by many famous persons. These include Beethoven, Grieg, J. S. Bach (where he was inspired to compose the Brandenburg Concertos), Dumas, Chopin, Brahms, Liszt, Schumann, Wagner, Tchaikovsky, Paganini, Peter the Great, Bismark, Maria Theresa, Goethe, and Queen Elizabeth I of England.

Today, the town of 60,000 population, has about one million visitors and treats 80,000 patients per year. The geothermal water consists mainly of Na, HCO_3, SO_4, and Cl, with a TDS of 6.45 g/l. Research by balneologists have shown that the greatest success with these waters is achieved in the treatment of chronic illnesses of the digestive system (intestinal and stomach), and a number of metabolic troubles. Long-term results are achieved particularly in cases of illnesses of the bile ducts and liver. Good results have also been achieved in the treatment of diabetes. The water cure significantly reduces the cholesterol level in the blood, making the prophylactic treatment of vascular and cardiac illnesses possible too. Treatment takes place at Spa V (the former Elizabeth Baths), and the Thermal Spa Sanatorium (capacity of 553 beds) which includes a large open-air swimming pool filled with mineral water (capacity 52 persons).

Leakage of thermal springs into the Tepla River bed through the aragonite beds, have affected the flows of the springs used for curative purposes. As a result, a program to seal the river bed was started in 1935. A clay-cement mixture is used to seal the bottom and any new excavation in the city is not allowed below 367 m elevation. New wells have been drilled to provide alternate supplies of curative drinking water; however, balneologists are concerned that this may change some of the chemical properties of the original hot springs. The water is being monitored for any possible changes.

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