



Environmental Services, Inc.

**AN ANALYSIS OF THE TAKE  
AND JEOPARDY FLOWS  
FOR THE FOUNTAIN DARTER  
INCLUDING POTENTIAL FLOWS  
REQUIRED BY THE ENDANGERED  
INVERTEBRATES OF COMAL SPRINGS  
HJN 020257 HCP**

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## 1.0 INTRODUCTION

Based upon the US District Court's Amended Judgment in the Sierra Club vs. Secretary of Interior lawsuit, the US Fish and Wildlife Service (USFWS or the Service) produced a series of springflow determinations regarding survival and recovery and critical habitat of threatened or endangered (T/E) species found at Comal and San Marcos Springs.

Table 1 presents the take and jeopardy flows developed by the USFWS. For this report, we are concerned primarily with those values for the fountain darter (*Etheostoma fonticola*) for the Comal System.

Horizon Environmental Services, Inc. (Horizon) was asked by its client Steven Quarles of Crowell and Moring, LLP, who represents the San Antonio Water System (SAWS), to examine all relevant data to determine on what basis the USFWS made the take and jeopardy determinations. Were those values based upon data or inference? In the time since 1993, has the USFWS or others developed data that can support those take and jeopardy values or perhaps suggest other levels as appropriate?

As well, since the 1993 determination of take and jeopardy flows at Comal for the fountain darter, 3 species of aquatic invertebrates have been listed as endangered: the Comal Springs dryopid beetle (*Stygoparnus comalensis*), the Comal Springs riffle beetle (*Heterelmis comalensis*), and the Peck's Cave amphipod (*Stygobromus pecki*). To date, the USFWS has not determined take and jeopardy flows for those 3 species. This report will discuss whether any of those species is likely to have the same or higher take and jeopardy flows as the fountain darter.

TABLE 1

**EDWARDS AQUIFER MINIMUM SPRINGFLOW FOR MAINTAINING LISTED SPECIES AT  
COMAL AND SAN MARCOS SPRINGS  
(Minimum springflow determined by USFWS)**

| SPECIES                                    | MINIMUM FLOW (cubic feet/second) |
|--|----------------------------------|
| <b>"TAKE" LIMITS</b>                       |                                  |
| <b>Comal Springs</b>                       |                                  |
| Fountain Darter<br>(without snail control) | 200                              |
| (with snail control)                       | 150                              |
| <b>San Marcos Springs</b>                  |                                  |
| Fountain Darter                            | 100                              |
| San Marcos Gambusia                        | 100                              |
| San Marcos Salamander                      | 60                               |
| Texas Blind Salamander                     | 50                               |
| <b>"JEOPARDY" LIMITS</b>                   |                                  |
| <b>Comal Springs</b>                       |                                  |
| Fountain Darter<br>(without snail control) | 150                              |
| (with snail control)                       | 60                               |
| <b>San Marcos Springs</b>                  |                                  |
| Fountain Darter                            | 100                              |
| San Marcos Gambusia                        | 100                              |
| Wild Rice                                  | 100                              |
| San Marcos Salamander                      | 60                               |
| Texas Blind Salamander                     | 50                               |

Crowell and Mooring, representing SAWS, in an effort to review the methodology and data utilized by the USFWS in making its take and jeopardy determinations, filed a Freedom of Information Act (FOIA) on the USFWS on 15 April 2003. Horizon has utilized all the information received from the FOIA plus major studies performed after the original flow determinations, such as the Instream Flow Assessment for the fountain darter performed by Hardy et al. (2000), the Habitat Conservation Plan (HCP) documents and associated studies produced to date for the Edward Underground Aquifer Authority (EUAA), and results of various studies by regulatory agencies, consultants, and universities.

Section 2 of this report will discuss what was concluded concerning the development of take and jeopardy flows after a review of the FOIA documents. This section will emphasize the important physiological and habitat criteria necessary to determine take and jeopardy flows. Second, the USFWS Instream Flow Assessment performed subsequent to the determination of take and jeopardy flows will be discussed as it relates to those flows. Third, the HCP documents will be reviewed as they pertain to the USFWS take and jeopardy values.

Section 3 will provide a discussion of potential springflows required by 3 endangered invertebrate species from Comal Springs. Because less has been written or is known concerning flow requirements for these species, this section will review the life histories, physiology, and ecology to provide a basis for assessing possible flow requirements.

Section 4 will provide a discussion of the validity of the current take and jeopardy flows and how might those numbers be affected by flows potentially required by the invertebrates.

## 2.0 REVIEW OF TAKE AND JEOPARDY VALUES FOR THE FOUNTAIN DARTER

### 2.1 INSIGHT FROM THE DOCUMENTS RECEIVED UNDER THE FOIA REQUEST

Horizon received copies of all materials produced by USFWS under the FOIA Request. Due to a number of factors, not the least of which was the relatively short time allotted by the court for the USFWS to make the take and jeopardy determinations, no coordinated studies, experiments, etc. were performed by the USFWS to determine take and jeopardy flow levels.

Based upon the 15 April 1993 take and 15 June 1993 jeopardy determination documents, it is clear the USFWS relied on available information and interviews with various experts to make its best professional judgment to determine the springflows. USFWS notes that because sufficient data were not available, a conservative approach was taken in developing flow estimates to ensure that irrevocable harm would be unlikely to occur to listed species. Further, they noted that the Service was in the early stages of a multiyear study to collect the necessary data. This ultimately led to the review draft of the Instream Flow Assessment for the fountain darter at Comal referred to herein as Hardy et al., 2000. To date, this study has not been finalized.

Much of the FOIA material is in the form of notes from meetings with agency personnel or various experts on the USFWS team or specific interviews with experts. Much of the factual information available in the FOIA submissions was discovered prior to the original trial. Much of it is anecdotal or the result of isolated observations, and judgment calls were solicited. Examples of such information include the following.

From Alicia Shull's notes on 15 November 1991 concerning interim plans for Edwards Aquifer/Springflows, it is obvious that neither the take nor jeopardy numbers were determined at that point. The meeting was staffed by 6 biologists from the Texas Parks and Wildlife Department (TPWD) and USFWS. The questions for discussions were:

"What level would take occur?"

"Biologically, are there several trigger levels?"

"When does harm first occur?"

"What lowest flow to maintain spp?"

There was a notation that "Easier to relate it to aquifer levels than flows." However, elsewhere in the FOIA materials, Paul Thornhill (hydrologist) states the reverse and notes that gauged flows are more reliable than aquifer levels. No one offered any flow values for take or jeopardy, at least as recorded in the notes, at this meeting.

In 3 subsequent meetings, there were notes concerning disparities in water well elevations, reference to water quality analysis, an observation that someone (Moss?) had begun to collect darters (as a rescue effort?) between 630 to 625 feet aquifer elevations. There was an isolated note that Tom B (Brandt?) will look at 200 cubic feet per second (cfs) and 25 cfs increments down from there, followed by a request for "Other studies needed?"

Whiteside (Southwest Texas State University) and Moss (TPWD) both concluded that water depths of 4 to 6 inches deep were necessary for the darter support. Whiteside felt that way because the "moss" grows 2 to 3 inches tall, and 4 inches would cover it.



Moss had sampled Comal Springs runs on 5 July 1990, when the habitat was reduced, but the note indicated that he couldn't guarantee any darters died. The water was 4 to 6 inches deep and the lowest he had collected darters from. Flow was 60 cfs on that day.

Gary Garrett (TPWD) in another note from a meeting on 14 February 1992 between TPWD and USFWS indicated 10 inches of water depth was "probably a little more than they needed." He wasn't sure, but thought 10 inches of depth would equate to 300 cfs.

The testimony transcripts for Dr. Whiteside and Dr. Moss indicate they thought the 4 to 6 inches of water depth was necessary for the darter. Dr. Clark Hubbs's (University of Texas) testimony stated that 12 inches of water depth was necessary to support the darters. He further indicated that darters would migrate to the lake, encounter warmer water, and stop reproducing under low flow conditions.

Whiteside noted that most of the darters he found were in the backwater areas, not areas of heavy flow. Dr. Moss also testified that he was aware that TPWD personnel caught darters in less than 4 to 6 inches of water.

In a 25 February 1993 meeting of Shull, Thornhill, and Kowis, it was noted at Spring Lake in San Marcos the flow would have to drop quite a bit before the temperature would change.

Notes by Alisa Shull from a 24 February 1993 meeting with Randy Moss and Kevin Mayes (TPWD) state that "think long term near 100 cfs (San Marcos)—but not much to base that on."

Also, a note that San Marcos has never been below 46 cfs and it would be "very risky to assume have enough knowledge to go below." Probably a reference to an interim flow meeting on 20 November 1991 at TPWD, during which Gary Garrett indicated that 46 cfs was lowest recorded flow at San Marcos. He added there was no biological basis to look any lower.

Another note states that both Comal and San Marcos populations are required to be maintained to avoid jeopardy. (Note that from 1960 to 1975 there were no fountain darters at Comal, as documented over time by Hubbs, Schenck and Whiteside and Espey Huston and Associates.)

Another note not supported by data was that "to preserve the ecosystem need water in 3 spring runs over long term—so above 100 cfs for water quality." At an Interim Flow meeting on 20 November 1991, it was noted that on 5 July 1990 spring runs 1 and 2 at Comal Springs were dry at 60 cfs, but spring run 3 had flow and darters. Randy Moss and Roy Kleinsasser felt that vegetation was most important and therefore there needs to be water of sufficient depth to cover the vegetation. At 212 cfs in spring run 1, there is enough depth over algal mats for suitable habitat for darters.

At Comal Springs, the take values for the darter are 200 cfs but only 150 cfs with control of the giant rams-horn snail (*Marisa cornuarietis*). Likewise, USFWS jeopardy limit for the darter falls from 150 cfs to 60 cfs with snail control. In the FOIA submission document of 22 February 1993 (discussions with Tom Arsuffi of Southwest Texas State University), there are no direct statements as to why the take and jeopardy values could be reduced so significantly if snails were controlled. It is clear from the notes attributed to Arsuffi that snail abundance is negatively related to water depth and current velocity. The snail, native to South Central

America and northern South America, is limited by low temperatures. Arsuffi thought the limit would be about 60° Fahrenheit (F). Overall, he thinks that velocity is more critical than water temperature in the Comal System.

Arsuffi indicated that 100 cfs was a critical level for the snail at Comal Springs because at this level more shallow water habitats exist around islands and current velocities are lower. He noted that the snails do well on *Ludwigia* and *Vallisneria*, that they don't prefer but will eat Texas wild rice, and that they don't do well on *Cabomba*. Arsuffi noted that he thinks the vegetation is experiencing a permanent change in which *Potamogeton* was becoming a dominant species.

Arsuffi indicated that if the aquifer level were maintained at 640 feet (150 cfs) mean sea level (MSL) to 650 feet (200 cfs) MSL, there would not be explosions in numbers of snails at Comal Springs. Further along in the interview notes, Arsuffi indicated that by eating vegetation and darter eggs, the snail could be a significant dramatic impact (jeopardy) to the darters.

Beyond these comments, no definitive reason in the FOIA materials was found supporting the modified take or jeopardy flows with snail control.

A great deal of FOIA materials received concerned Texas wild rice in the San Marcos River. Much of the bulk was raw data. There were no documents included that systematically analyzed the flows necessary for wild rice. During a 22 February 1993 with Paula Power and Jackie Poole, a number of observations concerning wild rice were made. Apparently, they have some data on differences in herbivory at different depths attributable to a variety of an organisms. However, field observations made by Jackie Poole in 1989 found

mixed results for plants in shallow reaches. Paula Power noted that she saw the giant ramshorn snail on the roots of wild rice. Neither she nor Jackie Poole had seen them on the plants themselves. Both feel that dams in the river cause negative impacts by creating too much depth and low velocity. Paula Powers thinks velocity is as important as depth, but they had not assessed flow and depth separately.

A note was made that lots of sediment running into the river were causing problems such as gravel bars near University Drive. Jackie Poole notes that lots of rocky, shallow areas prevent plants from establishing.

Both Poole and Power noted that as water gets shallower in the San Marcos River, herbivory goes up. They did note that they felt the snail probably ate other plant species first. Areas of no flow do not have wild rice plants. They note that 1989 flow levels could cause more uprooting of existing plants. One hundred or 110 cfs was given as the breaking point. Power notes that 16 inches of water is the critical level. At 24 inches of depth, plants are sensitive and vulnerable, whereas 31 inches of water is considered the low end of the ideal optimum range. Aside from depth, Power thinks velocity needs to be high enough to keep leaves submerged. She notes that in Spring Lake the birds (coots and swans) seem to be having an impact on plants.

There is nowhere presented in the FOIA documents a single set of notes, paper, or meeting results that clearly indicates how the USFWS determined any of the take or jeopardy flows it published in 1993. By examining the various meeting and interview notes, the following emerges:

### Comal

212 cfs – Moss and Kleinsasser feel that vegetation cover is very important for darter habitat.

At 212 cfs, all vegetation in Spring Runs 1 to 3 would be covered, according to them.

200 cfs – Reference to fact that Tom Brandt would study effects of 200 cfs and increments of 25 cfs lower. No data referenced.

200 to 150 cfs – Arsuffi estimate of flow necessary to prevent snail from getting out of hand.

60 cfs – Flow on 5 July 1990 referred to repeatedly by experts as having 4 to 6 inches of water in Spring Run 1. Both Moss and Whiteside individually saw that habitat. That amount of flow covered the vegetation even though no flow was coming from the orifices of Spring Runs 1 and 2.

### San Marcos

100 to 110 cfs – Power and Poole felt that flow level was breaking point for damage to wild rice.

100 cfs – Shull's notes indicate that 100 cfs is probably the long-term flow necessary—but not a lot to base that on.

In a USFWS Take Document of 8 March 1993 (never finalized), the rationale for take and jeopardy values for the fountain darter were discussed. The presence of the giant ramshorn snail dominates the rationale for protection. The document notes that, above 190 cfs in 1991, the loss of vegetation seen at lower flows (77 cfs in 1989 and 120 cfs in 1990) was avoided.

The document also states that Moss reviewed the literature and found that 10 cm (4 inches) of water depth is the minimum required by darters. The report goes on to note that at Comal Springs below 200 cfs, a small portion of vegetated habitat is dewatered in Spring Run 1 and that by the time flow reaches 150 cfs, noticeable changes in the spring runs occur, which warrants the assumption take has occurred due to loss of habitat.

In the discussion of jeopardy levels, it was pointed out that both the Comal and San Marcos populations are required to prevent jeopardy. In 1989, when Whiteside and Brandt collected darters in the spring, the darters appeared thin. Springflow was 67 cfs, and rams-horn snails had denuded large portions of Landa Lake, while the spring runs were more exposed due to low water. The USFWS contends that if flows in the 60 to 80 cfs range had continued, the majority of darters in the spring runs, lake, and river below would have been eventually eliminated. Fish collected in the lake were thin as well. This was attributed to a lack of food. In this report, USFWS notes that flows in excess of 100 cfs would eliminate this problem. But in the 15 June 1993 jeopardy document, the Service raised this value to 150 cfs and allowed that, with snail control, the flows could drop to 60 cfs for short periods, at which point elevated water temperatures would become a concern.

In the take and jeopardy analysis for the wild rice of San Marcos, some data analysis was presented to justify a 100 cfs take/jeopardy flow for the rice. However, the rationale for the fountain darter take/jeopardy value was primarily that since the darter lives in the same area and needs less habitat depth than the rice, they would be protected by 100 cfs.

The Service goes on to note that the Espey Huston and Associates 1975 report predicted that, on days when air temperatures exceed 29° Celsius (C) and water flows are

below 100 cfs, water temperatures at and below Hays County Road would exceed 26° C in the San Marcos River. Temperatures at 26° C would, according to the Service, cause loss of habitat and reproductive capability. Therefore, flows in excess of 100 cfs are necessary to prevent jeopardy. In fact, the temperature only peaked at 26° C during that simulation. The diel variation was 22.6 to 26° C at 100 cfs. The station in question was near Thompson Island and is generally at the downstream reach of darter habitat. As a result, all areas above Station 6 would not reach 26° C in the simulations at 100 cfs. Furthermore, the report goes on to note that recommended flows to protect the darter would be:

(a) 40 cfs instantaneous minimum flow

(b) 80 cfs monthly average flow

(c) 100 cfs minimum annual average flow

Therefore, the Espey Huston and Associates report did not predict the dire consequences represented in the Service report.

## 2.2 USFWS INSTREAM FLOW ANALYSIS

Hardy et al. (2000) performed an Instream Flow Assessment for the USFWS. Only the review draft is currently available. They utilized 2 analytical techniques to assess the effect of flow on fountain darter habitat at the Comal Springs System. One set of analyses (Presence/Absence Study) simulated a series of flow conditions ranging from 30 to 300 cfs (Table 2). They note that at 150 cfs and below, the simulations indicate that usable habitat

declines. At 100 cfs, the usable habitat was predicted to be 90.5% of that at 300 cfs. As flow declined to 60 and 30 cfs, the habitat declined to 75% and 60% of that at 300 cfs, respectively.

Hardy et al. (2000) note that, from 150 to 100 cfs, most of the decline is due to hydraulic factors and water temperature. Below 100 cfs, temperature and other factors such as lower water surface elevations contribute to the decline. As the flows drop, the models predict temperature limitation will spread downstream from upper portions of Landa Lake and upstream from the lower Comal River.

Hardy et al. (2000) use 80° F or greater as a cutoff point for unsuitable thermal conditions. Overall, the highest flow rate produced the most usable area for the darter and remained high down to 150 cfs. Landa Lake produced the most usable area at all flows ranging from 50 to 63% of the total suitable habitat at a given flow rate. This is about the same as Linam et al.'s (1993) estimate that Landa Lake comprised 52.2% of the suitable habitat. According to Linam et al. (1993), the old channel contained 31% of the suitable darter habitat, while the new channel contained only 16.5%. At 300 cfs, the old channel only accounts for 25% of the habitat and the new channel 15% in Hardy et al.'s (2000) analysis. Furthermore, in Linam's analysis the old channel has far and away the highest amounts of desirable vegetation types such as filamentous algae and *Ludwigia*.

Therefore, if the average catch rates in Linam's study are multiplied by Linam's vegetative cover types square footage amounts, the old channel ends up with 54.4% of the predicted darters in the Comal system, while Landa Lake is predicted to contain about 32%, and the new channel only has about 14% of the darters in the system.



**TABLE 2**  
**SUITABLE FOUNTAIN DARTER HABITAT PREDICTIONS**

| Total<br>springflow<br>rate (cfs) | Predicted Suitable Fountain Darter Habitat Area |                                   |  |                                   |                                  |
|-----------------------------------|---|-----------------------------------|--|-----------------------------------|----------------------------------|
|                                   | Landa Lake<br>(ft <sup>2</sup> )                | New channel<br>(ft <sup>2</sup> ) | Main spring<br>runs 1 to 3<br>(ft <sup>2</sup> ) | Old channel<br>(ft <sup>2</sup> ) | Total area<br>(ft <sup>2</sup> ) |
| 300                               | 811,900   | 210,800                           | 18,000   | 344,200                           | 1,384,900                        |
| 150                               | 798,000   | 218,900                           | 13,100   | 344,100                           | 1,374,100<br>(99.2%)             |
| 100                               | 680,600   | 220,400                           | 10,700   | 341,300                           | 1,253,000<br>(90.5%)             |
| 60                                | 544,900   | 223,400                           | 6500   | 267,300                           | 1,042,000<br>(75.2%)             |
| 30                                | 524,300   | 178,900                           | 2900   | 125,400                           | 831,500<br>(60%)                 |

Source: Hardy et al. (2000).

The second analysis Hardy et al. (2000) utilize is the simulation of weighted usable area (WUA). "Since the benthic warmwater fountain darter is so different from the traditional Instream Flow Incremental Methodology (IFIM) species, habitat variables emphasized for the darter habitat analysis had to be re-evaluated compared to traditional PHABSIM [physical habitat simulation system] approaches" (Hardy et al., 2000).

Because of the presence/absence model's (habitats with values below 0.45 may still have some use for darters) lack of precision, "...a hybrid approach was decided upon that used the traditional IFIM WUA approach as opposed to a multivariate equation, but replaced substrate and cover with vegetation, which is a key variable important for the fountain darter" (Hardy et al., 2000). Vegetation was categorized according to darter usage.

$$WUA = (\text{cell area}) \times (\text{velocity factor}) \times (\text{depth factor}) \times (\text{temperature factor}) \times (\text{vegetation factor}).$$
 One-way analysis of variance (ANOVA) testing showed significant differences in darter densities as assessed over a range of velocities (Hardy et al., 2000).

Modeling WUA results for the Comal River system below the old channel diversion structure indicated that a combined flow rate of 150 cfs, 110 cfs for the new channel and 40 cfs for the old channel, resulted in the highest combined WUA of 109,662 ft<sup>2</sup> (Table 3).

**TABLE 3**  
**MODELING WUA RESULTS FOR THE COMAL RIVER SYSTEM BELOW THE OLD**  
**CHANNEL DIVERSION STRUCTURE**

| New<br>Channel<br>Flowrate<br>(cfs) | Old<br>Channel<br>Flowrate<br>(cfs) | Combined<br>Flowrate<br>(cfs) | Old<br>Channel<br>WUA<br>(ft <sup>2</sup> ) | New<br>Channel<br>WUA<br>(ft <sup>2</sup> ) | Lower<br>Comal<br>WUA<br>(ft <sup>2</sup> ) | Combined<br>WUA<br>(ft <sup>2</sup> ) |
|-------------------------------------|-------------------------------------|-------------------------------|---|---|---|---------------------------------------|
| 0                                   | 30                                  | 30                            | 8476  | 0   | 0   | 8476                                  |
| 5                                   | 25                                  | 30                            | 8391  | 16,621                                      | 0   | 25,013 – 26.1%                        |
| 10                                  | 20                                  | 30                            | 8170  | 19,621                                      | 0   | 27,791                                |
| 20                                  | 10                                  | 30                            | 6405  | 25,206                                      | 12,566                                      | 44,177 – 46.0%                        |
| 0                                   | 40                                  | 40                            | 19,887                                      | 0   | 0   | 19,887                                |
| 10                                  | 30                                  | 40                            | 9727  | 19,621                                      | 0   | 29,348 – 30.6%                        |
| 5                                   | 35                                  | 40                            | 21,020                                      | 16,534                                      | 0   | 37,554                                |
| 20                                  | 20                                  | 40                            | 6405  | 24,183                                      | 12,566                                      | 43,154 – 45%                          |
| 10                                  | 40                                  | 50                            | 21,243                                      | 19,621                                      | 0   | 40,865                                |
| 20                                  | 30                                  | 50                            | 9727  | 23,452                                      | 12,566                                      | 45,744 – 47.7%                        |
| 45                                  | 30                                  | 75                            | 9727  | 26,358                                      | 11,737                                      | 47,822                                |
| 35                                  | 40                                  | 75                            | 21243                                       | 22,572                                      | 11,737                                      | 55,552                                |
| 70                                  | 30                                  | 100                           | 9509  | 46,758                                      | 13,613                                      | 69,880 – 72.8%                        |
| 60                                  | 40                                  | 100                           | 21,243                                      | 42,732                                      | 11,064                                      | 75,039                                |
| 95                                  | 30                                  | 125                           | 9266  | 59,305                                      | 11,248                                      | 79,819 – 83.2%                        |
| 85                                  | 40                                  | 125                           | 20,639                                      | 61,256                                      | 11,173                                      | 93,068                                |
| 120                                 | 30                                  | 150                           | 9266  | 75,862                                      | 9654  | 94,783 – 98.8%                        |
| 110                                 | 40                                  | 150                           | 20,639                                      | 79,492                                      | 9531  | 109,662                               |
| 170                                 | 30                                  | 200                           | 9266  | 73,708                                      | 12,954                                      | 95,928                                |
| 160                                 | 40                                  | 200                           | 20,639                                      | 75,591                                      | 10,080                                      | 106,310                               |

\*This analysis does not consider the upper part of Landa Lake, or the spring runs, for the micro habitat analysis, as these areas are not affected by the proposed flow split. These areas were considered and used in the analysis to include their effects on lower system temperatures at different springflow rates.

Source: Hardy et al. (2000)

"Water temperatures appeared to most affect the weighted usable fountain darter habitat area for the bypass analysis... Drying had a much smaller effect on weighted usable fountain darter habitat area." (Hardy et al., 2000.)

According to Hardy et al. (2000), "The fact that 2 different habitat modeling methods (WUA and multivariate presence/absence prediction) produced the same noticeable decrease in available fountain darter habitat between total Comal Springs flowrates of 150 cfs and 100 cfs is encouraging."

However, the 2 estimates differ greatly as to the percentage of habitat remaining at a given flow level. The WUA method produced appreciably lower habitat values from 100 cfs down, as does the presence/absence technique. Furthermore, the old channel is grossly minimized in WUA as opposed to the new channel. At 200 cfs with 30 cfs (approximately the flow most of the time) in the old channel, the old channel contains only 12.6% of the WUAs that the new channel does. This is completely contradictory to Linam et al.'s (1993) results as well as reversed from Hardy et al.'s (2000) presence/absence results.

Horizon concurs with Hardy et al. (2000) that the old channel should be a major recipient of flow during low-flow periods due to the very high number of darters present. Table 3 demonstrates that as long as 30 to 40 cfs is directed down the old channel, habitat can be preserved. Horizon collected water temperature data in 2 locations along the old channel in 1996 during a low period. Samples were collected just above the railroad trestle and just below the last dam before the confluence with the new channel.

| Date         | cfs | Upstream° C | Downstream° C |
|--------------|-----|-------------|---------------|
| 2 July 1996  | 95  | 26.5        | 25.5          |
| 12 Aug. 1996 | 84  | 25          | 25            |
| 19 Aug. 1996 | 83  | 24.5        | 25            |
| 26 Aug. 1996 | 117 | 24.5        | 24            |
| 6 Sept. 1996 | 142 | 24          | 24            |

Flow trended upward from that time and temperature stayed at 23 to 25° C until December 1996. With these temperatures and a continuous 30 cfs input, Horizon believes that the WUAs and the suitable areas would be maintained.

### 2.3 INDICATORS OF HYDROLOGIC ALTERATION – RANGE OF VARIABILITY APPROACH

Legitimate criticisms of instream flow techniques and their bias toward single species rather than ecosystem integrity have led to a number of other approaches to flow assessment (Castleberry et al., 1996; Crow and Sharp, 1997; Hart et al., 1996; and Richter et al., 1996). One methodology, Indicators of Hydrologic Alteration (IHA) analysis, was developed by the Nature Conservancy to quantify the consequences of anthropogenic activities on stream hydraulics (Richter et al., 1996). IHA analysis relies on recorded or modeled hydrological data to set discharge parameters that approximate the natural intra- and inter-annual flow regime. The biological significance of this range of discharges must then be assessed and confirmed (Richter et al., 1996).

Hydrological data may be garnered from stream gauges, weirs or well records and should include any known perturbations (Richter et al., 1996). After the data set is determined, 32 ecologically relevant hydrologic parameters are calculated from pre- and post-impact data.

These parameters can be grouped according to qualities that define the hydrologic regime 1) magnitude and timing of monthly water conditions; 2) magnitude and duration of extreme (minima and maxima) water conditions; 3) Timing of annual extreme water conditions; 4) frequency and duration of high and low pulses; and 5) rate and frequency of water condition changes. Statistical measurements of central tendency (mean) and dispersion (coefficient of variation) are calculated for each parameter (Richter et al., 1996). Each post-impact condition can then be quantified statistically as a percent deviation of the pre-impact condition.

#### 2.3.1 BIO-WEST RVA Study

Techniques used in IHA were adapted in a Range of Variability Approach (RVA) flow assessment of Comal Springs (BIO-WEST, 2002c). Daily streamflow data for the study was taken from US Geological Service (USGS) records from 1934 to 1996. Range of variability statistics were calculated for 33 hydrological parameters believed to be ecologically significant to the Comal Springs system. Next, a management target was selected for each parameter. The aim of the target values is to include annual IHA parameters within the natural range of variation or inter-annual measure of dispersion (BIO-WEST, 2002c). If implemented, the RVA values can then be used to create management strategies that facilitate the hydrologic goal. Ecological ramifications of the management plan should be evaluated through extensive biological and hydraulic monitoring. Utility of the target values and success of the river management plan must be reviewed annually by comparing actual stream parameters to the RVA target values (BIO-WEST, 2002c).

RVA target values based on hydrologic parameters from Comal Springs were used to evaluate outputs from groundwater pumpage models developed by LBG-Guyton and Associates using the Edwards Aquifer model (GWSIM-IV) (BIO-WEST, 2002c). Pumping scenarios modeled ranged between 150,000 and 475,000 acre-feet/year by means of 25,000 acre-feet/year increments (Habitat Conservation Plan/Environmental Impact Statement [HCP/EIS] draft – Appendix B, 2000). The percent of time modeled outputs were outside of RVA target ranges was calculated as:

$$\frac{\text{Observed} - \text{Expected}}{\text{Expected}} \times 100$$

where groundwater output is the observed and the RVA targets are the expected (BIO-WEST, 2002c).

Results from groundwater modeling most closely fit the RVA parameters (historical data) when pumping ranged from 275,000 to 325,000 acre-feet/year (BIO-WEST, 2002c). Additionally, withdrawals in this range should provide surface discharges above 0 cfs. Although withdrawals of 150,000 acre-feet/year would result in continuous discharges of 150 cfs or greater, higher discharges would exceed RVA parameters. Hydraulic alteration values increase noticeably at withdrawals of 375,000 acre-feet/year and above (BIO-WEST, 2002c).

### 2.3.2 Flow Recommendations in the RVA Study

The RVA study was a portion of a biological impact assessment in support of the HCP/EIS for the Edwards Aquifer. The second phase of the biological impact assessment involved a discussion concerning, and recommendations, for flow for the various listed species

based upon "the best available biological information as it relates to past and projected springflows" (BIO-WEST, 2002c).

The following statements concerning the various listed species at Comal Springs are the assessments of BIO-WEST (2002c):

- Comal Springs Dryopid Beetle (*Stygoparnus comalensis*). The species is subterranean in nature and does not require a significant discharge from springs to survive. A constant springflow that continually covers the spring orifice should prevent harm to the population. Conservative minimum flow was estimated to be 30 cfs.
- Comal Springs Riffle Beetle (*Heterelmis comalensis*). Specific springflow requirements remain unknown. BIO-WEST calls for historic flow conditions to err on the side of caution. However, they note that the species has tendencies to follow flows, including movement downward in sediment toward water. This raises questions about where to look for the elmids as opposed to only the upper layer of rocks sampled exclusively to date. The survival of the species during past droughts and dewatering suggests that the species must have adaptive mechanisms to deal with such events. BIO-WEST concludes that with more studies data could be developed that would allow a less conservative approach to flows to protect the species. Conservative minimum flow estimate is 100 cfs.
- Peck's Cave Amphipod (*Stygobromus pecki*). Little is known of the species' habitat requirement. It is a subterranean species and should be protected if spring orifices



remain covered with flowing water. The conservative minimum flow estimate is 30 cfs.

- Fountain Darter (*Etheostoma fonticola*). BIO-WEST relies on the IFIM results of the USFWS for effects of flow. They do emphasize that, at 100 cfs, the only areas significantly reduced in suitable habitat are springflow runs 1 to 3. They point out that this area at 300 cfs only accounts for 1.3% of the habitat in the Comal Springs system as calculated by the USFWS. They also note based upon historical data (Linam, 1993; PBS&J, 2000; Hardy et al., 2000) that the old channel supports a significant fountain darter population and that maintaining sufficient flows in this reach is a "greater priority than in the other reaches." Currently, the area is limited to a maximum flow of 40 cfs, and they note that when flow was reduced from 20 cfs to 10 cfs in the old channel, it resulted in only a 10% decrease in suitable habitat. They conclude by hypothesizing that if darters are shown to be capable of withstanding elevated temperature and aggregating in areas of optimal habitat, then temporary loss of some amount of suitable habitat could be acceptable. They make no comments as to take or jeopardy levels. Their conservative minimum springflow estimate is 60 cfs.

Table 4 presents the context in which the BIO-WEST conservative minimum flow estimates should be viewed. The table portrays the absolute number of days, the percentage of time, and most consecutive days that a modeled aquifer pumpage scenario would fall to 0 and below the conservative minimum flows of 30, 60, and 100 cfs that BIO-WEST ascribed to the listed species at Comal Springs. The flow scenarios range from 150,000 to 550,000 acre-feet per year (ac. ft./year).

BIO-WEST has assessed 4 HCP pumpage scenarios and determined that based upon the results in Table 4 the minimum conservative flow estimates adequately protect the species for the HCP category 1 (275,000 to 325,000 ac. ft./year) and the HCP category 2 (150,000 to 275,000 ac. ft./year). BIO-WEST notes that HCP Category 3 (325,000 to 375,000 ac. ft./year) presents a moderate risk to species since the duration of time that the species would experience the conservative minimum flows has increased to a level BIO-WEST finds problematic. The Category 4 pumpage rates of 375,000 to 550,000 ac. ft./year in BIO-WEST's opinion increased the duration of the conservative minimum flow too much and produce high risk to the species.

The conservative minimum flows only apply when the duration of that flow is limited to an acceptable amount of time, such as in HCP plans 1 and 2. The conservative minimum flows produce moderate risk under the HCP 3 plan and is unacceptable according to BIO-WEST under the HCP 4 plan. The default flows acceptable for the species without a low or moderate risk HCP plan in place to restrict pumpage are not defined for the fountain darter or *Heterelmis comalensis* and is given as sufficient flow to cover the spring orifices for *Stygoparnus comalensis* and *Stygobromus pecki*.

**TABLE 4**

The (a) absolute number of days, (b) percentage of time, and (c) most consecutive days that each modeled pumping scenario would fall below the given springflow level in Comal Springs based upon the period of record (63 years; 22,995 days). Values for the period of record are also included.

| Modeled Pumping Scenario | (a)    |        |        |         | (b)   |        |        |         | (c)   |        |        |         |
|--------------------------|--------|--------|--------|---------|-------|--------|--------|---------|-------|--------|--------|---------|
|                          | 0 cfs  | 30 cfs | 60 cfs | 100 cfs | 0 cfs | 30 cfs | 60 cfs | 100 cfs | 0 cfs | 30 cfs | 60 cfs | 100 cfs |
| 150                      | 0      | 0      | 0      | 0       | 0.0%  | 0.0%   | 0.0%   | 0.0%    | 0     | 0      | 0      | 0       |
| 175                      | 0      | 0      | 0      | 0       | 0.0%  | 0.0%   | 0.0%   | 0.0%    | 0     | 0      | 0      | 0       |
| 200                      | 0      | 0      | 0      | 0       | 0.0%  | 0.0%   | 0.0%   | 0.0%    | 0     | 0      | 0      | 0       |
| 225                      | 0      | 0      | 0      | 0       | 0.0%  | 0.0%   | 0.0%   | 0.0%    | 0     | 0      | 0      | 0       |
| 250                      | 0      | 0      | 0      | 147     | 0.0%  | 0.0%   | 0.0%   | 0.6%    | 0     | 0      | 0      | 84      |
| 275                      | 0      | 0      | 32     | 460     | 0.0%  | 0.0%   | 0.1%   | 2.0%    | 0     | 0      | 31     | 236     |
| 300                      | 0      | 0      | 279    | 885     | 0.0%  | 0.0%   | 1.2%   | 3.8%    | 0     | 0      | 165    | 659     |
| 325                      | 0      | 218    | 621    | 1,431   | 0.0%  | 0.9%   | 2.7%   | 6.2%    | 0     | 154    | 238    | 1,027   |
| 350                      | 152    | 448    | 1,042  | 2,342   | 0.7%  | 1.9%   | 4.5%   | 10.2%   | 126   | 220    | 665    | 1,054   |
| 375                      | 389    | 970    | 1,751  | 3,597   | 1.7%  | 4.2%   | 7.6%   | 15.6%   | 206   | 660    | 1,049  | 1,150   |
| 400                      | 852    | 1,640  | 2,849  | 4,788   | 3.7%  | 7.1%   | 12.4%  | 20.8%   | 603   | 1,046  | 1,142  | 1,695   |
| 425                      | 1,440  | 2,692  | 4,073  | 6,228   | 6.3%  | 11.7%  | 17.7%  | 27.1%   | 918   | 1,237  | 1,403  | 2,832   |
| 450                      | 2,406  | 3,982  | 5,628  | 8,489   | 10.5% | 17.3%  | 24.5%  | 36.9%   | 1,296 | 1,423  | 1,817  | 2,925   |
| 475                      | 3,775  | 5,749  | 7,490  | 10,863  | 16.4% | 25.0%  | 32.6%  | 47.2%   | 1,239 | 2,525  | 2,943  | 3,990   |
| 500                      | 6,004  | 7,977  | 10,446 | 12,841  | 26.1% | 34.7%  | 45.4%  | 55.8%   | 3,014 | 3,093  | 3,721  | 4,600   |
| 536                      | 9,813  | 11,849 | 13,350 | 15,504  | 42.7% | 51.5%  | 58.1%  | 67.4%   | 4,303 | 4,450  | 9,200  | 9,341   |
| 550                      | 11,149 | 12,823 | 14,429 | 16,558  | 48.5% | 55.8%  | 62.7%  | 72.4%   | 8,766 | 9,263  | 9,309  | 9,600   |
| Period of Record         | 144    | 237    | 532    | 1,236   | 0.6%  | 1.0%   | 2.3%   | 5.4%    | 144   | 213    | 333    | 674     |

### 3.0 STATUS, ECOLOGY, AND INFLUENCE OF SPRINGFLOW ON THE ENDANGERED INVERTEBRATE SPECIES COMAL SPRINGS

In 1997 three aquatic invertebrates, the Comal Springs riffle beetle, *Heterelmis comalensis*, Peck's cave amphipod, *Stygobromus pecki*, and the world's only known stygobiontic (groundwater dwelling) dryopid beetle, *Stygoparnus comalensis*, were classified as endangered, under the Endangered Species Act by the USFWS.<sup>1</sup> The organisms have been collected from a limited number of spring ecosystems in Comal and Hays counties in central Texas. These springs are artesian outlets of the Edwards Aquifer (Balcones Fault Zone), which is the primary habitat of the subterranean amphipod and dryopid beetle. Potential reductions in water quality and quantity are considered the foremost threats for these species.

Early efforts with regard to these organisms concentrated primarily on species description and taxonomic distinction. While relevant segments of these works will be discussed, further information relating to the morphology and systematics of these species can be found in Barr and Spangler (1992), Bosse et al. (1988), Holsinger (1967 and 1977).

#### 3.1 STATUS SURVEYS

Prior to listing, 2 status surveys (Arsuffi, 1993; Barr, 1993) were funded by the USFWS to determine the range and incidence of the species in question. Arsuffi (1993) was contracted to examine the distribution of *Heterelmis comalensis*, *Stygobromus pecki*, and *Stygoparnus comalensis* during the spring and summer of 1991. Surveys were conducted at San Antonio and Salado Springs in Bexar County; San Marcos, Sink, and Fern Bank Springs in

<sup>1</sup> Note concerning nomenclature. Due to the length of the common names of the invertebrates and the shared specific name of the 2 beetles, they will be referred to by their complete scientific or Latin names.

Hays County; and Hueco and Comal Springs in Comal County. Samples were collected using a Hess sampler (tubular device with a downstream collection net) in riffle and run habitats. A dip net and handpicking were used to examine "non-benthic" habitats (snags, large rocks, leaf litter etc.) In this study, *Heterelmis comalensis* were collected only from "orifice three" at Comal Springs; *S. pecki* was collected only from Comal Springs, openings 1, 2, and 3; and *Stygoparnus comalensis* was not collected at all. Arsuffi points out that the low occurrence of *S. pecki* and absence of *Stygoparnus comalensis* in samples does not automatically indicate that they are either restricted or rare. Rather, they are difficult to collect due to their stygobiontic (groundwater) habit, and methods used in this study were devised to collect epigeal (surface dwelling) organisms. Arsuffi does suggest the use of drift nets, placed over spring openings, as an alternative means of collecting the groundwater invertebrates.

The second survey supported by USFWS was conducted in August 1992. Occurrence of the 2 hypogean (subterranean) species, *Stygoparnus comalensis* and *S. pecki*, in Edwards Aquifer springs was assessed (Barr, 1993). Nine spring complexes in the San Antonio sub-region of the aquifer were examined. These included San Antonio and San Pedro Springs (Bexar County); Comal, Gruene, and Hueco Springs (Comal County); and Fern Bank, San Marcos, and Sink Springs (Hays County). Areas adjacent to each springhead were sampled by manually agitating the substrate upstream of a D-frame aquatic net (kick net method). Additionally, drift nets were placed over spring outlets when possible. Ranges for both species were extended beyond the type locality (location where type specimen was collected) of Comal Springs. A single *S. pecki* was found at Hueco Spring I and 13 *Stygoparnus comalensis* at Fern Bank Springs (Barr, 1993). Museum collections (Edwards Aquifer Research and Data Center at Southwest Texas State University, Texas Memorial Museum at the University of Texas,

Entomology and Biology Departments at Texas A & M University, and The Dallas Natural History Museum) were examined for further occurrence of the 2 species. None were found.

All 3 of the listed invertebrates have been shown to occur outside of Comal Springs. *S. pecki* has been collected at Hueco Springs, *Stygoparnus comalensis* at Fern Bank Springs, and *Heterelmis comalensis* at San Marcos Springs, which issue within Spring Lake (Barr, 1993). More recently, samples taken at Comal, Fern Bank and Hueco Springs during the spring and summer of 2003 confirmed the presence of *Stygoparnus comalensis* and *S. pecki*, respectively (Fries et al., 2003). Furthermore, numerous *Heterelmis comalensis* were found along the margins of Spring Lake in March of this year (C. Thompson USFWS per. comm.).

Other unusual invertebrates encountered include a previously unknown troglobitic bidessine dytiscid beetle, *Comaldessus stygius*, from Comal 1, 3, and 4; two subterranean amphipods *Mexiweckelia hardeni* (Comal 2 and 4); and *Seborgia relict*a (Comal 3) (Barr 1993). *Comaldessus stygius* (Coleoptera: Dytiscidae: Bidessini) was first collected in 1992 from Comal Springs, Texas (Barr, 1993). Although it has been described (see Spangler and Barr 1995), no official status surveys or habitat analyses have been conducted. However, because it has been encountered so rarely and because of its association with the Edwards Aquifer, it will possibly become a species of concern in the future.

### 3.2 THE COMAL SPRINGS RIFFLE BEETLE, *Heterelmis comalensis*

The Comal Springs riffle beetle, *Heterelmis comalensis* Bosse et al. (1988), (Coleoptera: Elmidae) was first collected from Comal Springs, Comal County, Texas, in 1976. It

is believed that *Heterelmis comalensis* evolved from an isolated population of *Heterelmis glabra*, a species restricted to the Big Bend region of southwest Texas (Bosse et al., 1988). Although slightly smaller and paler, *Heterelmis comalensis* is otherwise indistinguishable from its distant ancestor (Bosse et al., 1988). As the hind wings of both species are reduced and incapable of flight and the distance between the 2 populations is considerable, it is likely that the species have been separated for some time. It is possible that the ancestral population was divided during the most recent ice age (3 million years ago); however, zoogeographical and DNA analyses have not been conducted.

Furthermore, it was thought to occupy only the shallow (2 to 10 cm) riffle areas adjacent to the Comal Spring orifices 1, 2, and 3. More recent surveys have located numerous beetles along the shoreline of Landa Lake and within the lake itself at depths up to 5 feet (BIO-WEST, 2002A). Additionally, further sampling of Spring Lake at San Marcos during March of 2004 greatly increased the known population (C. Thompson USFWS, per. com.) This extended range of conditions implies that the species may be more adaptable than previously believed (BIO-WEST, 2002C). In all instances, beetles were collected from areas adjacent to spring openings, and in some cases they actually appeared to aggregate around spring upwellings (BIO-WEST, 2002A).

### 3.2.1 Riffle Beetle Ecology

Members of coleopteran family Elmidae, commonly known as the riffle beetles, are commonly found in areas of swift current (Merritt and Cummins, 1993). In arid and semiarid regions, they often occur in temporary streams and may retreat to the damp substrate as the stream dries (Brown, 1987). All life stages are aquatic with the exception of the pupae.

Females attach eggs to submerged rocks, wood, or vegetation (Brown, 1987). Incubation occurs in 5 to 15 days, with the larval stage lasting 6 to 36 months, depending on the species and ambient conditions. Pupation occurs above the water line in damp sand or organic material. Following emergence, adults of most species have a brief flight period before entering water. After this they are no longer capable of flight. Mating occurs following this aerial period (Arsuffi, 1993).

Anecdotal reports of the longevity of elmids larvae and adults under laboratory conditions, while limited, are impressive. Often the adults survived exposure to extremely high (>38°C) and low (approximately 4°C) ambient temperatures (Cole, 1957; Brown, 1973). In some instances, the beetles were kept in capped vials or jars with no supplementary aeration for several years, although the water was changed or added as necessary. Brown describes a 10-gallon, aerated aquarium habitat, where he has kept adult *Macronychus* sp. and *Microcylloepus* sp. for a period of 10 years (1973). Although larvae brought from the field were able to survive for several years, most failed to pupate. Brown notes that while such endurance may not be typical of wild populations, both adult and larval elmids are capable of surviving many years under adverse conditions. Though longevity records of *Heterelmis comalensis* are incomplete, adult *Heterelmis vulnerata* have been kept in aquaria for several years (Brown, 1973).

If wild populations of *Heterelmis comalensis* have similar life spans, there are important implications with regard to survivability. Short-lived species have a narrow window in which to reproduce and perpetuate their lineage. Environmental stress during such critical periods can prove catastrophic for such organisms. Conversely, organisms that live multiple



years as adults and are able to persist during periods of stress may reproduce later when conditions are more favorable.

As adult riffle beetles enter the water, they capture a thin layer of air in hydrofuge hairs or setae that cover much of their body. Tracheae (respiratory structures), beneath the beetles' hind wings open directly into this film of gas, called a plastron. The plastron acts as a physical gill, allowing oxygen to diffuse into the structure as the insect depletes it (Chapman, 1982). The hydrofuge hairs that make up the plastron of adult elmids may be as numerous as several million per m<sup>2</sup>. And although this results in very effective "physical gill," it is thought to limit elmids to heavily oxygenated waters. Elmid larvae respire with the aid of terminal gills extruding from the anus, covered by a hinged operculum (Merritt and Cummins, 1993). With regard to food, most elmids, adults and larvae consume microorganisms, algae, and debris scraped from the surrounding substrate (Brown, 1987). And though elmids are often observed in assemblages, they are more likely attracted to the same microenvironment than truly gregarious (Brown, 1987).

There is evidence that macrozoobenthos migrate into the substrata during drought conditions to avoid desiccation. This suggests that the substrate provides refuge during periods of physical disturbance (Wallace, 1990). In the literature, numerous examples are given of beetles from the family Elmidae found in habitats other than those within the stream. These include observations within the wetted substrata or hyporheic zone of permanent streams. (Bishop, 1973; Godbout and Hynes, 1982; McElravy and Resh, 1991; Poole and Stewart, 1976; Williams, 1984; Williams and Hynes, 1974). In some distributional surveys, elmid larvae were more common in the hyporheic zone (depths of 10 to 70 cm) than on the substrate surface of inundated streams (Godbout and Hynes 1982). In another study species and life-stage differences were observed (Williams and Hynes, 1974). Seasonality, or effects due to annual

precipitation, was also observed (McElravy and Resh, 1991). Occurrence of adult and larval Elmidae in damp substrate (depths of up to 50 cm) below dried temporary stream channels was noted in California (Bell, 1972) and Texas (Brown, 1987) streams. In one of the most remarkable accounts of riffle beetle survivorship, dry substrate collected up to 6 weeks after surface flow ceased in an Australian intermittent stream produced viable larvae when it was saturated in a laboratory (Boulton et al., 1992). Taxonomic exactitude was not given in a number of these studies and the organisms collected were simply referred to by family (Bishop, 1973; Godbout and Hynes, 1982; Williams, 1984). Furthermore, because of the difficulty in identifying early elmids instars (larval stages) to species, immatures of the species are often referred to as "elmids larvae."

In a 1993 status report, Arsuffi suggests that *Heterelmis comalensis* may be able to burrow during times of drought and survive periods of environmental stress. Although migration into the substrate has not been documented for *Heterelmis comalensis*, downward movement of individuals, toward a source of flow, has been observed (BIO-WEST, 2002B). It is thought that, for beetles in run habitat, use of this strategy is limited by the depth of the damp substrate (Arsuffi, 1993). However, as long as a wetted corridor connects the runs to Landa Lake, individuals should be able to follow receding waters. Additionally, the tendency of *Heterelmis comalensis* to collect around areas of springflow, suggests that they could retreat into these orifices in periods of extremely low flow (BIO-WEST 2002A). Adult *Heterelmis* were collected from dried riffles in Waxahatchee, Texas, although they were probably of the species *Heterelmis vulnerata* (Brown, 1987).

### 3.2.2 Habitat Study for *Heterelmis comalensis*

In a cooperative project, TPWD and USFWS endeavored to determine the habitat requirements and seasonal distribution of *Heterelmis comalensis* (Bowles et al., 2003). The 4 principal spring-runs at Comal Springs were examined in July and October 1993 and January and April 1994. Using maps of the area and a grid overlay, 1-meter square cells were selected at random from the runs. Approximately 10% of the run streambed was sampled as 278/m<sup>2</sup> cells. Cells, which did not fall completely within the wetted area of the run, were eliminated from the study. The rationale behind this restriction was maximization of sampling efforts (D. Bowles per. comm.) However, this almost certainly resulted in the under-sampling of edge habitats. Habitat conditions recorded for each cell include: size (run dimensions), canopy, riparian cover, substrate composition, instream vegetation, water depth, current velocity, dissolved oxygen, conductivity, pH and distance from spring source. Biological samples were taken by manually agitating the substrate while a drift-net was held downstream to collect invertebrates. Physical-chemical and hydraulic conditions varied little among individual runs and sampling dates (Bowles et al., 2003). Two elmids (riffle beetles) known from Comal Springs, *Heterelmis comalensis* and *Microcyloepus pusillus*, were considered during this survey. No relationship was detected between abundance of the target organisms or their location within the stream run and water depth, current velocity or distance from the spring orifice. Instead, they appeared to be randomly distributed within spring-runs. Although larvae, pupae, and adults were collected from both species, larvae were the most commonly encountered life stage, pupae the least. In most cases, densities for *M. pusillus* were higher than those for *Heterelmis comalensis*. Reported maximum densities for *Heterelmis comalensis* larvae were 5.3/m<sup>2</sup> (Comal 2, July), for pupae, 0.2/ m<sup>2</sup> (Comal 3, October) and for adults, 2.5/m<sup>2</sup> (Comal 3, July). In contrast, densities for *M. pusillus* reached 125.8/m<sup>2</sup> for larvae, 5.8/m<sup>2</sup> for pupae and 60.7/m<sup>2</sup> for adults (Bowles et

al., 2003) When habitat characteristics of the two species were compared, *Heterelmis comalensis* appeared to prefer more shallow waters with higher velocities than *M. pusillus*. Yet, the authors are quick to point out that this disparity may be due to the fact that so few *Heterelmis comalensis* were collected (Bowles et al., 2003). *M. pusillus* has functional flight wings and has been collected extensively in Texas (Bowles et al., 2003).

Both beetle species were collected most often from cells that contained some vegetation, although correlation with a particular plant or assemblage could not be determined (Bowles et al., 2003). It is possible the beetles were usually found in vegetated areas because hydrophytes (water plants), algae and mosses occur extensively in the runs.

Substrate size may have influenced habitat selection in the case of *Heterelmis comalensis*. Both species were found in samples from spring-runs 1, 2, and 3, where gravels and cobbles (8 to 128 mm) are prevalent (Bowles et al., 2003). Comal 4 differs from the other spring runs in that as it approaches Landa Lake, it takes on lentic characteristics, becoming slow-moving and silt-bottomed. Only *M. pusillus* was collected from Comal 4. The absence of *Heterelmis comalensis* from Comal 4 run, which has a substrate composed of sands, silts, and small gravels (<32 mm) may indicate lack of tolerance for small particles.

The year-round presence of larvae, pupae, and adults of both species indicates that life stages are concurrent and emergence of adults, continuous (Bowles et al., 2003). Asynchrony (irregular emergence) may be a response to unpredictable discharge. In a temperate region, such as central Texas, the environment is conducive to year-round emergence and ovipositioning for many species.

Bowles declined to surmise concerning life history of *Heterelmis comalensis* due to the complexity and longevity of the family Elmidae (Bowles et al., 2003). As adult *Heterelmis comalensis* collected from the wild have been kept alive for over a year in the laboratory, it is possible that such limited sampling of this organism misrepresents its true life history (Bowles et al., 2003).

During the study, approximately 10% of inundated spring-run surface was sampled by agitating the substrate into a downstream drift net (Bowles et al., 2003). These areas, which were considered to be bare of *Heterelmis comalensis*, were recolonized within 3 months. No source of recolonization was suggested. This study, along with the BIO-WEST (2002A) Landa Lake survey may indicate that the presence of water and its quality are the principal constraints on this species.

The authors suggest the establishment of refugia stock, once the habitat requirements of *Heterelmis comalensis* are established and can be duplicated in the laboratory (Bowles et al., 2003). Take and jeopardy numbers for the fountain darter may be sufficient, but sampling for the habitat study occurred at flows greater than the historic mean. Bowles et al. (2003) recommend a range of spring discharges that imitate recorded flows as long as springflow was not stopped permanently or for an extensive period.

### 3.2.3 Habitat and Population Study *Heterelmis comalensis*

A survey conducted by BIO-WEST in 2001 demonstrated that *Heterelmis comalensis* occupied a number of habitats previously unknown (BIO-WEST, 2002A). Prior sampling had been limited to the 4 major spring-runs in Landa Park, all but 1 of which yielded *Heterelmis*

*comalensis* (Arsuffi, 1993; Barr, 1993; Bosse et al., 1988, and Bowles et al., 2003). Field collection took place during 2001 (summer and fall samples) and 2002 (winter samples) and concentrated on the western shoreline of Lake Landa. Small spring outlets occur along the lake margin in this area. In locations where springflow could be discerned, rocks were turned over and examined for *Heterelmis comalensis* (BIO-WEST, 2002A). Using a quantitative benthic frame (0.25 m<sup>2</sup>), the adult population for this type habitat was estimated at 2.0 per m<sup>2</sup> (BIO-WEST, 2002A), as compared to 2.5 per m<sup>2</sup> in the spring runs (Bowles et al., 2003). Additionally, in the fall of 2001 and the winter of 2002, SCUBA was used to examine points of springflow in deeper areas of Landa Lake. The locations of these openings were made evident by bubbles rising into the water column. Although not abundant, *Heterelmis comalensis* were collected at depths of up to 4 feet (BIO-WEST, 2002A). Beetles were not found on substrates where silt accumulation was heavy. The results of this study demonstrate that *Heterelmis comalensis* occupies a range of habitats and is not limited to spring-runs as previously believed (BIO-WEST, 2002A).

#### 3.2.4 Laboratory Flow Response Study for *Heterelmis comalensis*

A laboratory study conducted by BIO-WEST (2002B) examined the response of *Heterelmis comalensis* to a range of flows through an artificial matrix. Vertical movement through 8 horizontal layers and orientation with regard to current were assessed. Some trials included obstructions in the layers to mimic the natural reduction of interstitial spaces with increasing depth. *Heterelmis comalensis* were generally observed moving downward and toward the source of flow, though results obtained were not statistically significant. The beetles tended to collect at the lowest level regardless of current. In trials where flows were decreased over time to no-flow conditions, beetles moved to lower regions despite obstructions. As water

was withdrawn from the experimental chamber, the beetles followed the receding water. When lateral flows were present only in upper levels, beetles remained in these layers instead of moving down. While there is no evidence that the beetles have specific flow requirements, they do seem to orient with the source of flow. If *Heterelmis comalensis* has evolved to advance in the direction of upwelling flow within the Comal system, traditional benthic sampling may only reveal a fraction of the entire population (BIO-WEST, 2002C).

### 3.3 SUBTERRANEAN INVERTEBRATE SPECIES AT COMAL SPRINGS

Both *Stygobromus pecki* and *Stygoparnus comalensis* are groundwater obligates, meaning that their principal habitat is both subterranean and aquatic, in this case the Edwards Aquifer. Stygobiontic organisms (groundwater obligates) share many morphological traits with cave-dwelling species (troglobites). Troglomorphological characteristics include vestigial eyes or absence of eyes (microphthalmia or anophthalmia), reduced pigmentation, thin and soft integument (exoskeleton), absent or reduced wings (in insects), small size, slow metabolism and development, long life and late maturity and low fecundity (Spangler, 1986; Gibert et al., 1994)

#### 3.3.1 Dryopidae Ecology

Dryopidae, commonly known as the long-toed water beetles, are primarily known from the tropics (Merritt and Cummins 1996). Only 3 aquatic genera are found in US: surface-dwelling *Helichus* and *Postelichus* and *Stygoparnus* from the Edwards Aquifer. Like the Elmidae, dryopid adults are non-swimming aquatic beetles commonly found on rock surfaces in riffle areas in lotic systems (Brown, 1972). As with other members of the superfamily

Dryopoidea, most are small, slow-moving and unobtrusive (Brown, 1972). The life-history of the Dryopidae differs from other aquatic insects in that the larvae are terrestrial or subaquatic, while the adults are truly aquatic (Merritt and Cummins, 1996). Adults breathe using a plastron, as described for the Elmidae, and are thus reliant on water with sufficient levels of dissolved oxygen.

#### 3.3.1.1 *Stygoparnus comalensis*

The Comal Springs Dryopid Beetle, Barr and Spangler, (Coleoptera: Dryopidae), another protected insect, is the world's first known stygobiontic Dryopidae (Barr and Spangler, 1992). *Stygoparnus comalensis* was first collected from the Comal 2 springhead and adjacent run in 1987. Since that time its known range has been extended to Comal Springs (orifices 3 and 4) and Fern Bank Springs in Hays Co., Texas. Although adults of the species are collected from springheads and associated runs, they are considered groundwater obligates (Barr and Spangler, 1992). Because the larval forms of the family Dryopidae are generally terrestrial, those of *Stygoparnus comalensis* are believed to inhabit the soil, roots, and debris lining the ceiling of subterranean cavities (Barr and Spangler, 1992). This non-aquatic life-stage may allow the species to aestivate (undergo diapause or become dormant during a warm or dry season) when surface waters are reduced. It is not known why the adults enter surface waters or whether they are able to return to their subterranean habitat. Most specimens were collected from low volume springs and seeps (Barr, 1993).

The subterranean genus *Stygoparnus* is thought to be most closely related to *Helichus*, as the 2 share some morphological characters. However, the 2 are easily separated



by *Stygoparnus comalensis*' vestigial eyes, 8-segmented antennae, and reduced flying wings (Barr and Spangler, 1992). Additionally, the exoskeleton of *Stygoparnus comalensis* appears reddish-brown and thin to the point of transparency (Barr and Spangler, 1992). Reduced pigmentation is common to subterranean organisms (Spangler, 1986).

Though little is known about the life history of *Stygoparnus comalensis*, observations made on specimens in the laboratory are worth noting. Adult specimens have been kept in aerated bowls and flow-through aquaria containing various substrates and spring/aquifer water (Barr and Spangler, 1992, Fries et al., 2003). In the laboratory specimens utilized all rock surfaces for resting and "grazing", but frequented the tops least. However, several spent considerable time just below the water's surface and one was observed out of water on top of a wet rock for several minutes. In addition, one specimen participated in what appeared to be "plastron grooming" or augmenting its plastron with air bubbles obtained from the water-air interface (Barr and Spangler 1992). Mating behaviors have been observed between captive adults; however, reproduction has not (Fries et al., 2003).

Larvae collected from the wild were returned to the San Marcos National Fish Hatchery and Technology Center (NFHTC) (Fries et al., 2003). They were kept in separate aquaria from adults and provided terrestrial retreats above the waterline. Regardless, *Stygoparnus comalensis* larvae collected from the wild soon die and none have been successfully reared in a laboratory. Perhaps individuals collected from within springflow are already in poor condition since their presumed habitat is terrestrial (Fries et al., 2003). Although in general *Stygoparnus comalensis* seem delicate and prone to injury, one specimen lived 21 months in the lab (Barr and Spangler, 1992). The authors attributed the high mortality observed to the weakness of the beetles' exoskeleton. With regard to insect cuticle, the sclerotisation or tanning process is the cross-linking of proteins that result in hardening of the exoskeleton (Chapman, 1982).

### 3.3.2 Amphipod Ecology

The principal habitat of *Stygobromus pecki* is a restricted portion of the Edwards Aquifer. Thus, opinions concerning habit, trophic relationships, and life history are generally speculative in nature. As a rule, amphipods are found in waters of consistently cold temperatures (Thorp and Covich, 1991). Amphipods require high dissolved oxygen concentrations and, as such, can be useful indicators of water quality. They usually demonstrate photonegativity or an aversion to light. Most species are attracted to flow and are said to be positively rheotactic. They hide in small spaces within the substrate, rock crevices, and root mats to evade predators and bright light (Thorp and Covich, 1991). With regard to food, amphipods appear to be opportunistic, utilizing available resources (Thorp and Covich, 1991). The primary food of *Stygobromus pecki* is likely detritus from surface organisms transported underground via recharge. Under favorable circumstances with regard to available food and water quality, population densities can become quite high (Thorp and Covich, 1991).

While most amphipods complete their life cycle within 1 year, some troglobitic species live up to 6 years. In surface species with an annual life cycle, females generally produce a single brood of eggs and populations exhibit seasonal peaks (Thorp and Covich, 1991). In contrast, cave species are known to bear multiple broods that contain fewer eggs. They also lack seasonality, resulting in overlapping life cycles (Thorp and Covich, 1991). Following fertilization, the eggs are held in a maternal pouch or marsupium until the fully developed young are released (Thorp and Covich, 1991).

Very few aquatic invertebrates are strong swimmers and most lotic (stream) species develop means to avoid current (Wallace and Anderson, 1996). Correspondingly, active dispersal of amphipods is limited by swimming ability, their attraction to interstitial spaces, and avoidance of light. In addition, passive dispersal of amphipods is restricted by lack of a desiccation-resistant life stage, such as diapause (Thorp and Covich, 1991).

#### 3.3.2.1 *Stygobromus pecki*

The third species of concern, Peck's Cave amphipod, *Stygobromus pecki* Holsinger (Amphipoda: Crangonyctidae) was first collected from Comal Springs in 1964 (Holsinger, 1967). Although a groundwater obligate, *Stygobromus pecki* is often collected in surface waters and is known from all 4 major springs and associated runs in Landa Park and from Hueco Springs, about 7 km north of Comal (Barr, 1993). Morphologically, *Stygobromus pecki* is a small (10.5 mm), laterally flattened, eyeless amphipod well suited to its underground environment. While little is known about the habitat requirements of *S. pecki*, its hypogean existence suggests that ground water quality is extremely significant.

In a 2003 study, wild-caught *Stygobromus pecki* were taken to the San Marcos National Fish Hatchery and Technology Center (NFHTC), where they were placed in 48-liter aquaria with flow-through systems containing water from Edwards Aquifer (Fries et al. 2003). Water was directed through a chilling unit and kept between 21 to 23° C. An assortment of substrates and food sources placed in aquaria (clay, glass, leaves, marbles, rocks, spawning mats, sticks, etc.) and the system darkened by wrapping black plastic around the outside. Food preference surveys were conducted by placing amphipods in separate smaller aquaria containing limestone, clay and dried leaves: pecan, elm, and anacua. It is thought that the

amphipods harvest fungi and bacteria that colonize leaves and other detritus. During the tests, *S. pecki* were observed in the pecan and elm leaves only. As a result, these leaves were added to communal tanks (Fries et al., 2003).

Gravid females, evident by the orange eggs in their brood sacks, were observed in the communal tank. They were placed in separate aquaria, as there have been some observations suggesting cannibalism (Fries et al., 2003). Females of *S. pecki* appear to carry about 10 eggs. Captive female produced an average of 5 offspring each (Fries et al., 2003). At the time this report was written, it was not known whether fertilization occurred in the laboratory or whether females were captured following fertilization. Similarly, the lifespan of captive *S. pecki* has not been determined as wild-caught individuals were still alive upon writing, having survived 5.5 months in captivity (Fries et al., 2003).

#### 3.4 SUMMARY OF OBSERVATIONS RELATED TO AQUIFER FLOW

All 3 protected invertebrate species were able to re-establish viable populations following the drought of record (including 5 months of no flow in 1956) and reduced flows in 1984 and 1990. While it is likely that such adverse conditions did not favor reproduction or growth, the reduced flow regime was tolerated by the species of concern. Furthermore, it is reasonable to presuppose that similar short-term conditions in the future would be endured (BIO-WEST, 2002C).

While little is known about mechanisms employed by the Comal species, many stream invertebrates are adapted to fluctuations in discharge. Generally, as water loss becomes detrimental, survival of aquatic invertebrates takes 1 of 2 approaches. Insects of

temporary streams often have a life history stage with which to avoid drought, such as a terrestrial or aerial adult, or a desiccation-resistant egg or pupae. If such strategies are not available, the aquatic form may migrate from the drying environment to a wetted one, such as a nearby pool or the hyporheic zone (Delucchi and Peckarsky, 1989). Although none of the species of concern have an aerial life-stage, both beetles are terrestrial as pupae. Since emergence of both is believed to occur year round, this terrestrial stage may provide a reserve "safeguard" during periods of reduced flow. Prolonged aestivation during this non-aquatic life stage is also feasible.

A valid concern with flow reduction is the accompanying decrease in dissolved oxygen. Because plastron efficiency is dependent on dissolved oxygen levels, water quality is important for both beetle species. However, laboratory observations indicate that *Stygoparnus comalensis* may actually enhance the plastron by forcing surface air bubbles down its body using its legs (Barr and Spangler, 1992). Other studies report adult Elmidae living in capped vials or jars of water with no supplementary aeration for several years (Brown, 1973; Cole, 1957). Thus, while diminished flows can result in lower dissolved oxygen, these species may have means to compensate under less favorable conditions.

Unlike the fountain darter, no USFWS take and jeopardy minimum springflow levels have been specified for the 3 protected invertebrate species found at Comal Springs. It has been questioned whether springflow minima set for the darter, 200 cfs for take and 150 cfs for jeopardy, are appropriate for the invertebrates as well (Bowles et al., 2003). When assessing the environmental impact of proposed pumping regimes, BIO-WEST (2002C) suggested conservative minimum flows for the subterranean invertebrates of 30 cfs when considered as part of an HCP pumpage limit of 375,000 acre feet or less. If no pumpage plan is in place, the

discharge should assure that the springheads remained inundated. Because USFWS models predict significant loss of run habitat when flows drop below 100 cfs, this minimum was recommended for *Heterelmis comalensis* (BIO-WEST, 2002C) again as part of the HCP pumpage limit of 375,000 acre feet. Additionally, BIO-WEST asserts that discharges of 60 cfs would supply adequate fountain darter habitat under the same HCP limits.

If providing the subterranean species access to surface waters is the sole intent of the 100 cfs flow, it is misplaced. Although *Stygobromus pecki* and *Stygoparnus comalensis* have been collected outside of spring orifices and associated runs, their morphology indicates they are not suited to life in surface waters. Whether they have the ability to return to the aquifer is uncertain, as the amphipod is a poor swimmer and the dryopid beetle does not swim at all (Barr, 1993; Thorp and Covich, 1991). When present in surface waters, they generally retreat to rock crevices and gravel to avoid predation. This being the case, the occurrence of these 2 stygobionts in the waters beyond the springheads of Comal Springs is incidental as survival of individuals is unlikely.

Some speculation exists concerning the habitat requirements of immature *Stygoparnus comalensis*. Because the larval forms of the family Dryopidae are generally terrestrial, those of *Stygoparnus comalensis* are believed to inhabit the soil, roots, and debris lining the ceiling of subterranean cavities (Barr and Spangler, 1992). For this reason, Barr (1993) assumes the species is limited to aquifer levels that allow adults access to springheads. However, if the aquifer were to recede, it is likely that suitable "terrestrial" habitat would be available underground, above the groundwater-air interface.

It is also doubtful that *Heterelmis comalensis* requires 100 cfs in discharge to provide suitable habitat. Distribution of *Heterelmis comalensis* is certainly influenced by immediate physical surroundings within the Comal System. However, surveys show that observed microhabitats vary greatly, from spring runs to springheads deep within Landa Lake. Correspondingly, *Heterelmis comalensis* has been found at a wide range of water depths (2 to 150 centimeters). As evidenced in other Elmidae, it is possible that *Heterelmis comalensis* is able to resist desiccation by retreating into the wetted substrate when surface flow is absent. For this reason, hyporheic habitats should be examined using standpipe wells (Leopold, 2001), artificial substrates (Bishop, 1973) or core samples (Williams and Hynes, 1974). The tendency of *Heterelmis comalensis* to seek out spring orifices may indicate that in times of low flows beetles retreat into springheads and are able to recolonize surface habitats as conditions improve. Alternately, *Heterelmis comalensis* may have survived past droughts by moving into the pools of Landa Lake where it is found under normal conditions. Other factors that may play a role in distribution are predation, inter-specific competition, intra-specific competition and hydraulic extremes such as drought or spates (flashfloods) and should also be explored.

#### 4.0 DISCUSSIONS AND CONCLUSIONS

The objectives of this report were to (1) assess the development and appropriateness of the 200 cfs take flow and 150 cfs jeopardy flow for the fountain darter at Comal Springs and (2) determine if the potential flow requirements for the 3 endangered invertebrates would be higher than the darter.

The monthly average flow for Comal from 1933 to 1990 was 292 (Hardy et al., 2000). Monthly means from 1934 to 1996 ranged from 253 (August) to a high of 302 (February) with an average of 284 (BIO-WEST, 2002c). According to Hardy et al. (2000), there is no substantive difference in habitat for the darter from 300 cfs down to 150 cfs. Therefore, it is clear that the take and jeopardy flows of 200 and 150 cfs, respectively, are clearly too high and are so conservative as to be meaningless for the intent they were established.

Based upon our review of the FOIA materials received from the USFWS, the take and jeopardy numbers were derived from a series of separate and unconnected data sources largely because, to the time of the Sierra Club lawsuit, no one had done a systematic study to define the take and jeopardy flows. As described in Section 2.1 of this document, once the lawsuit was filed, various experts were interviewed, committees were formed to study the issues, and testimony at the trial was given.

Since the darter was the only listed species at Comal during that time period, and since Comal Springs would be affected before the San Marcos Springs as the aquifer level drops, initially the discussion focused on the issue of a take of the darter at Comal Springs. Since this was most likely to occur in the spring runs in Landa Park, the level of available habitat



in the spring runs at different flow levels was important. Clearly, based on the discussion in Section 2.1, there was a diversity of opinion and several estimates were proffered.

The issue of whether a take of the fountain darter had or would occur focused directly on the predicted habitat that exists in the uppermost spring run (1) at Comal Springs. As established during the Sierra Club trial, this spring run area, which contains fountain darters, will be the first area of Comal Springs altered sufficiently to produce a take due to falling water levels in the aquifer. Paul Thornhill's testimony as well as that of Dr. Bobby Whiteside, Dr. Randy Moss, and Dr. Clark Hubbs focused on effects in this area of Comal Springs.

The most likely scenario to produce a take due to falling aquifer levels would be that the upstream portion of spring run 1 would become isolated from the lower portion of Spring Run 1 and Landa Lake. This isolated area would have to contain 1 or more fountain darters that, due to lowered water levels in the isolated area, either perished or were otherwise harmed or harassed by being subjected to degraded conditions from which they could not escape, as they would normally. According to the USFWS (1993), in this situation examples of harm or harassment could include the lack of food with resultant loss of condition, increased water temperature that affected normal functions such as feeding and/or reproduction, increased potential for predation, and even habitat insufficient to provide appropriate substrate upon which to lay eggs.

As long as there is a continuous connection between spring orifice 1 and downstream portions of the spring run 1, of sufficient water depth, darters will be able to move from 1 area of the spring run to another to select preferred habitat as usual. A take due to water level fluctuations, based upon Thornhill's data, would not occur above roughly 100 cfs springflow at Comal Springs because isolated areas that could trap darters would not occur.

The following review of testimony at the trial and available data supports the above contentions.

Thornhill's cross-section and flow data presented during deposition and the trial indicate a slightly deeper area roughly 25 to 35 feet in length immediately downstream of the spring orifice and just upstream of a gravel bar that represents the shallowest point in Spring Run 1 (Figure 1). Downstream of that point, even though some irregularities in depth occur, the bottom of the spring run generally tends to drop in elevation (e.g., water depth continually increases) to the confluence with Landa Lake. This is consistent with field observations by Horizon during 1994 and with the testimony given by Whiteside and Moss at the trial. Therefore, the limiting depth is the gravel bar very close to the spring mouth on spring run 1. By the time flows reach an area downstream roughly 150 feet from the gravel bar, the effect of the lake backwater on depth becomes a factor in maintaining water depth. Therefore, the area not subjected to lake backwater effects extends roughly 170 feet downstream of the spring orifice. The first walk bridge across spring run 1 is roughly 270 feet downstream of the spring orifice. Exhibit #226, as modified, presents an array of water depth profiles at various flows ranging from 118 cfs through 385 cfs total springflow at Comal Springs (Figure 1). Horizon's modifications of Exhibit #226 are the 4-, 6-, and 12-inch water depth lines over the flow profiles and the labels identifying the gravel bar, upstream limit of the lake backwater, staff gage, and first walk-bridge locations. Examining the flow profiles for values close to 190 and 220 cfs indicates that, at all points in the channel, water depth will vary from 6 inches at the gravel bar to roughly 9 inches elsewhere from the spring run mouth down to the first walk bridge. This amount of habitat at these water depths should not produce a take, according to

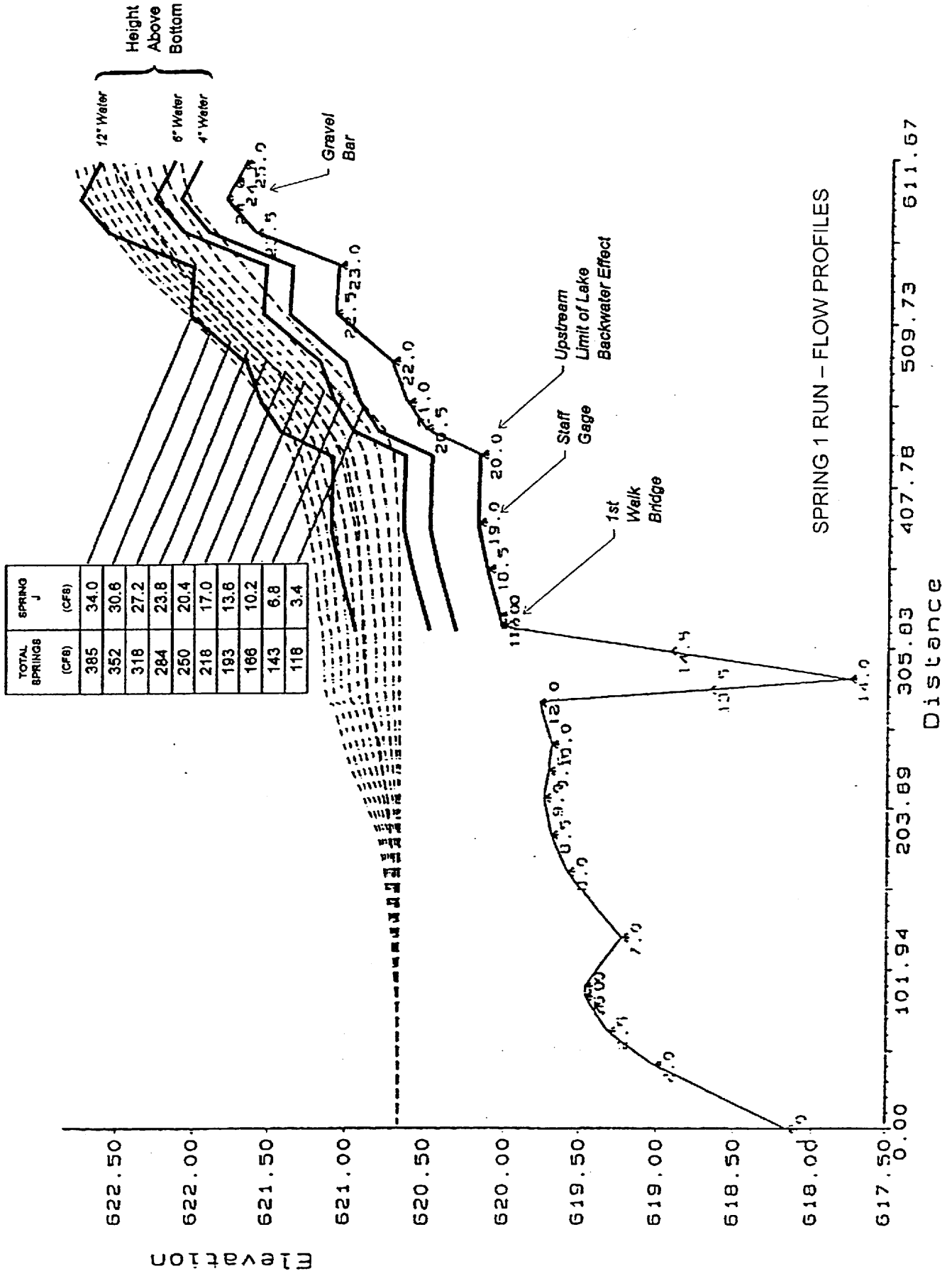


FIGURE 1 - Exhibit 226 as Modified by Horizon Environmental Services, Inc.

Dr. Moss's or Dr. Whiteside's testimony. Dr. Moss indicated a take could begin to occur at 4 to 6 inches of water depth and Dr. Whiteside indicated 4 inches of water depth was sufficient to prevent a take. Dr. Hubbs testified that a depth of 12 inches should be maintained; however, at the average flow (284 cfs) for the period of record (1930 to 1992), such a depth would only occur at the walk bridge and diminish upstream to approximately 9 inches in depth. Therefore, it seems that Hubbs's estimate of required depth would not be met over one half of the time over the period of record and is too high an estimate.

Drs. Whiteside and Moss both observed habitat conditions in spring run 1 below which spring 1 had ceased flowing (e.g., 60 to 80 cfs range). According to Exhibit #226 (see Figure 1), flow could drop to roughly 140 cfs before water depths less than 4 inches occur at the gravel bar, with the remaining areas above the walk bridge having more than 6 inches of water depth. The lowest springflow condition Thornhill modeled (118 cfs) would produce approximately 3 inches of water depth over the gravel bar and between 4 to 6 inches elsewhere over the remaining area downstream until backwater effects from Landa Lake caused depths of more than 6 inches about 170 feet downstream of the spring 1 orifice.

The area of the spring run upstream of the gravel bar is devoid of vegetation. Hubbs, Whiteside, and Moss all testified that habitat for darters is vegetated preferably with filamentous algae and less so by *Ludwigia*, although other vegetation species will also attract darters. The TPWD data collected and reported by Linam, et al. (1992), data from Brandt and Whiteside (undated), Schenck's thesis (1975), and Espey Huston and Associates (1975) all demonstrate that darter presence is invariably tied to submerged vegetation or algae being present. Vegetation in spring run 1 begins below the gravel bar described above. These same reports all show darter densities in preferred habitat much higher in Landa Lake, in the old Comal River channel, and in

the San Marcos River than those reported for spring run 1. Therefore, even though darters are found in spring run 1, the habitat ranks very low compared to preferred fountain darter habitat. Furthermore, Hubbs was correct in noting that greater than 12 inches of water depth is preferred by the darter at Comal, as this is borne out by the above-referenced studies. However, as demonstrated above, such conditions in the upper spring run do not occur consistently in spring run 1 even at the highest flow of 385 cfs as shown in Thornhill's Exhibit #226 (see Figure 1). This is further borne out by Horizon's monitoring data for the area from the first walk bridge upstream (see Figure 1), wherein flows ranging from 360 cfs to 400 cfs still failed to inundate the total spring run cross-section to a depth of 12 inches. At these flows the majority of the areas were well above 12 inches; however, the bulk of this area of spring run 1 contained less than 12 inches of water whenever the flows were less than 320 cfs from February 1996 through February 1999. A review of average monthly flows for the period 1930 to 1992 contained in LBG-Guyton (1994) indicates flows capable of producing 12 inches of depth throughout the upper spring run occurred in only 35 of the 744 months examined (4.7%).

Springflows of 200 cfs, which would maintain a minimum of 7 inches of water depth over the upper portion of spring run 1, have occurred in roughly 75% of the years from 1930 to 1992; however, they have not necessarily been maintained during the entirety of each year.

The 200 cfs take flow is also based upon the presence of the giant rams-horn snail. With aggressive snail controls, the USFWS take flow value would drop to 150 cfs. The area of spring run 1 presents very little habitat for the snail below the gravel bar and none above it (no vegetation). Furthermore, the snails' preference for vegetation does not include filamentous algae, the prime vegetation for fountain darter habitat. The snail does eat *Ludwigia*, also utilized by the fountain darter, which is found in spring run 1. However, water depths and flow velocities in the

area likely to first produce a take are not conducive to snail infestation. For these reasons, in spring run 1, the snail will not impact the darter population regarding a take under the conditions described. Furthermore, Hardy et al. (2000) indicate there is little difference in habitat available between 300 and 150 cfs springflow. Such flow conditions would limit snails, anyway. According to Hardy et al. (2000), explosion of the snail population would occur in Landa Lake between 80 and 120 cfs. Therefore, it is obvious that the take reduction for snail control is meaningless between 200 and 150 cfs.

Diminishment of the areal extent of spring run 1, as long as continuous habitat from the spring orifice to Landa Lake is available, should not constitute a take for the fountain darter at Comal Springs. Both Hubbs and Moss testified that darters would move in response to declining water levels. Whiteside, however, indicated that some may stay put in the vegetation until it is too late to move. Since no loss of habitat continuity will result at 190 to 220 cfs and since darters move around within habitat areas, it cannot be construed that they are being harassed or harmed at these flows. Darters finding unacceptable conditions in unvegetated areas will be able to move to vegetated areas downstream. This is true until flows diminish to the point where an area is cut off.

Finally, the issue of water temperature constancy being maintained at the 190 and 220 cfs levels is not a factor. Darters at Comal Springs are most abundant in the old river channel (Linam, et al., 1992), which receives less than 10 cfs continuously from Landa Lake and maintains water temperatures obviously suitable for darters throughout its length. The proximity of the spring discharges to spring run 1, i.e., along and immediately upstream, serves to maintain water temperatures in the spring run very near to aquifer conditions until flows in the run cease in the 50 to 60 cfs range.

From 29 February 1996 through 24 February 1999, Horizon personnel have measured water depth in spring runs 1 and 3 on 108 occasions. On each occasion, water depth was measured at 10 stations. Because 4 stations are transect stations, 26 water depths are measured each time. Two additional stations on the old river channel were added starting 6 July 1996. The data collected supports our contention that the 200 cfs take and 150 cfs jeopardy flow levels are not at all accurate and much too high. Based upon our water depth data, flows of 150 cfs would not even produce a take, much less cause jeopardy.

During Wiersema's May 1995 testimony before Judge Lucius Bunton, he indicated that, working with Dr. Robert Brandes on the historic hydrology of the upper spring run (run #1), he had concluded that flows as low as 118 cfs, as modeled by the plaintiff's expert Paul Thornhill, would still be sufficient to avoid a take. Based upon a comparison with Horizon's 1996 data, that conclusion is accurate. Our 14 June 1996 observations at 119 cfs springflow indicated that a gravel bottom pool had become isolated from the remainder of spring run 1. Flowing water still reached downstream areas by in-gravel flow. The isolated pool remained, but had continued to diminish in size through 17 August 1996, when the flows began to increase and the pool was no longer isolated because of increased water depths.

The isolated pool was sustained for approximately 3 months with no apparent flow from major spring orifices. This occurred during a period of continuous high air temperature days approaching or exceeding 100° F. USGS data for the Old River Channel and at gaging station #081690000 demonstrate that water temperatures were holding in the 24 to 26° C range. Temperatures in this range are well within the fountain darter's tolerance range.

Dr. Hubbs indicated in his affidavit that on 20 June 1996, he also collected 3 fountain darters in spring run 3. He concluded they were "in bad shape although in much better condition than the fountain darters collected in spring run 1."

Spring run 3 never had any areas isolated from other portions of the spring run or Landa Lake from 26 February 1996 through the remainder of the study. Spring run 3 is a generally deeper, faster flowing run than spring run 1. The 2 areas present quite different habitats, which largely accounts for the different species of fish Dr. Hubbs noted as present in his affidavit. Furthermore, in both spring runs 1 and 3, water temperatures remained in the 23° to 24° C range in the area Dr. Hubbs described during the entire low flow period in 1990. Neither the isolated pool area of spring run 1 nor most of spring run 3 provide preferred habitat for the fountain darter. But since the water temperatures were acceptable and the numbers of darters in the runs were low (based upon Dr. Hubbs's sampling), it is difficult to attribute the thinness of the darters to lack of food based upon flow reductions.

Schenck (1975), in his master's thesis concerning the fountain darter, clearly indicates that June is a low point between reproductive peaks for the fountain darter. Therefore, it is not surprising that Dr. Hubbs found no young in the isolated pool since no vegetation (preferred egg laying substrate) exist in that area and reproduction would be naturally at a low point when he sampled. Furthermore, based upon Horizon personnel's experience with metabolic rates in darters, it is not uncommon for darters just finishing a reproductive peak to lose condition and appear thin. These fish, because they have relatively high metabolic rates, can be thin even in the presence of adequate food. This is especially true when metabolism is shifting from a reproductive to a non-reproductive condition.



During the same period of flow in spring run 1, the lake, old river channel, and new river channel were all flowing well and maintaining habitat in those areas.

Only the very upper end of spring run 1 was low enough not to provide potential habitat for the fountain darter. That area represented well less than 1% of the total area available for the darter at Comal Springs.

Finally, regarding the fountain darter, if the duration of the event is as predicted for the HCP Category 1 (325,000 ac. ft./year pumpage), while there could possibly be a take due to stranding in spring run 1, or excessive snail herbivory in Landa Lake, the episode would conclude before the darters in the old and new channels were greatly affected because sufficient water would flow in both of these areas to protect the thermal regime. Therefore, no jeopardy would ensue due to that pumpage scenario.

With regards to the invertebrates, it is clear from Section 3.0 of this report that we believe that flows that protect the darter will protect the invertebrates. If the HCP Category 1 pumpage was in effect, BIO-WEST (2002C) indicates that flows of 30 cfs would only pose a low risk to the subterranean species (Peck's Cave amphipod and Comal Springs dryopid beetle). We don't believe that 100 cfs is necessary for the Comal Springs riffle beetle because of its wide distribution in the Comal System and adaptive mechanisms to drought conditions.

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